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13. ABSTRACT

This report presents a survey of environmental conditions - physiography, vegetation, and climate - which might affect military personnel and equipment above the 2,000-meter elevation in Central Asia. These highlands include some of the world's highest a and most inaccessible mountain ranges, such as the Himalaya, Karakoram, Pamir, Hindu Kush, Kun Lun Shan, Anme Machin, Tien Shan, Nan Shan, and Great Snowy Range, as well as the high plateaus of Tibet and the generally lower mountains of Mongolia. The study treats portions of Afghanistan, Bhutan, Burma, China (including all of occupies Tibet), India, Mongolia, Nepal, Pakistan, Sikkim, and the Soviet Union. It is organized in two parts: a general synopsis of environmental characteristics of the area as a whole, and a series of more detailed treatments by sections. For the latter, Central Asia is subdivided into five sections comprising the Sino-Burmese Ranges, Tibetan Plateau and associated ranges, Pamir Knot and associated ranges, Tien Shan and associated ranges, and the Mongolian Highlands. All of these except the Mongolian Highlands are shown in topographic and cultural maps at a scale of approximately 1:3,800,000. The distribution of terrain, vegetation, and climatic elements over the area as a whole is shown in a series of smaller-scale maps at 1:10,000,000.

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ENVIRONMENT OF THE CENTRAL ASIAN HIGHLANDS

Paul C. Dalrymple, et al

Army Natick Laboratories
Natick, Massachusetts

December 1970

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TECHNICAL REPORT

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by

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U.S. ARMY NATICK LABORAT
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Kaye R. Everett Sarah Wollaston

Environments Division

William C. Robison

ography Division

2

December 1970

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Sciences Laboratory
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FOREWORD

This study was undertaken at the request of the Office, Chief of Research and Development, Department of the Army, in order to provide background environmental information in support of studies of the problems encountered by troops operating at very high elevations. It has been supplemented by a contract study of the second-highest continent - South America - conducted along somewhat similar lines by the Batelle Memorial Institute.

This report is the result of a team effort by a group of earth scientists and cartographers in the Earth Sciences Laboratory. It was coordinated by Dr. Paul C. Dalrymple, Chief of the Regional Environments Division. Authors of the report, and portions for which they were principally responsible, were: Dr. Kaye R. Everett, landforms and water supply; Dr. William C. Robison, vegetation; Miss Sarah Wollaston, climate; and Mr. Andrew D. Hastings, Jr., glaciers and environmental stresses.

Dr. Terris Moore, consultant, served as expert advisor to the authors and made available his profound knowledge of the study area and of mountaineering in general. Dr. Moore's 1932 ascent of Minya Konka (with Burdsall and Emmons) was the highest climb by Americans until very recent years, and in 1959 his aircraft landings and takeoffs at 4,950 meters on Mt. Sanford, Alaska, constituted world altitude records.

Cartography was accomplished under the direction of Mr. Aubrey Greenwald, Chief of the Cartography Office, excepting maps 4, 21, and 22 which were prepared under an Army contract by the American Geographical Society. In-house cartographic work was performed by Mr. Greenwald, Miss Tenney Bennett, Miss Pernel Leuvelink, Miss Olive Lesueur, Mr. Andrew D. Hastings, Jr., and Mr. Jameson D. MacFarland. Initials on the individual maps identify the cartographers responsible for them.

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ABSTRACT

This report presents a survey of environmental conditions - physiography, vegetation, and climate - which might affect military personnel and equipment above the 2,000-meter elevation in Central Asia. These highlands include some of the world's highest and most inaccessible mountain ranges, such as the Himalaya, Karakoram, Pamir, Hindu Kush, Kun Lun Shan, Amne Machin, Tien Shan, Nan Shan, and Great Snowy Range, as well as the high plateaus of Tibet and the generally lower mountains of Mongolia. The study treats portions of Afghanistan, Bhutan, Burma, China (including all of occupied Tibet), India, Mongolia, Nepal, Pakistan, Sikkim, and the Soviet Union. It is organized in two parts: a general synopsis of environmental characteristics of the area as a whole, and a series of more detailed treatments by sections. For the latter, Central Asia is subdivided into five sections comprising the Sino-Burmese Ranges, Tibetan Plateau and associated ranges, Pamir Knot and associated ranges, Tien Shan and associated ranges, and the Mongolian Highlands. All of these except the Mongolian Highlands are shown in topographic and cultural maps at a scale of approximately 1:3,800,000. The distribution of terrain, vegetation, and climatic elements over the area as a whole is shown in a series of smaller-scale maps at 1:10,000,000.

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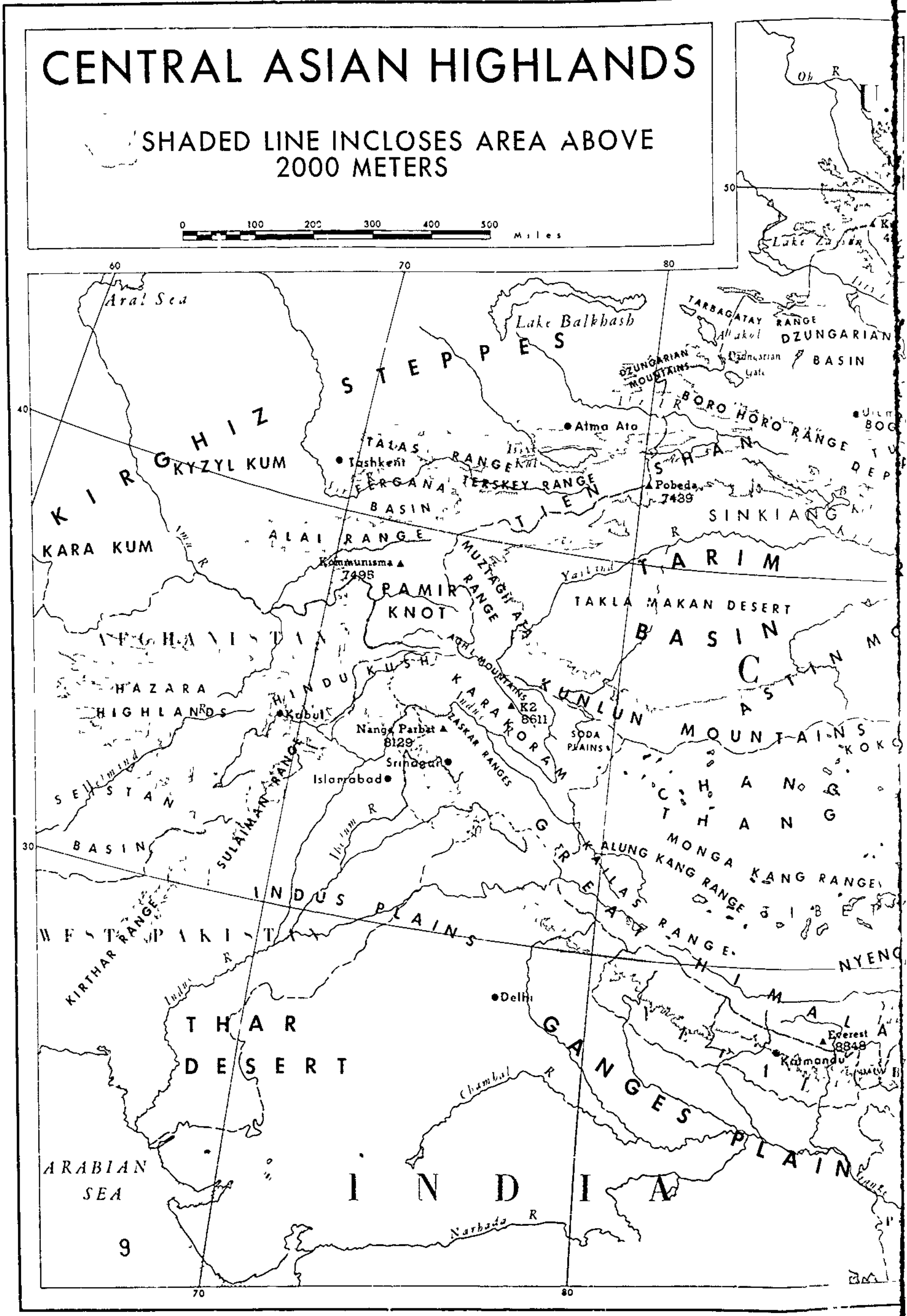
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0 100 200 300 400 500 Miles
Aral Sea
Lake Balkhash
KIRGHIZ STEPPES
KYZYL KUM
KARA KUM
Tashkent
TALAS RANGE
FERGANA BASIN
TERSKEY RANGE
Alma Ata
TIEN SHAN
Pobeda 7439
BORO HORO RANGE
TARBAGATAY RANGE
DZUNGARIAN BASIN
DZUNGARIAN MOUNTAINS
SINKIANG
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PAMIR KNOT
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Katmandu
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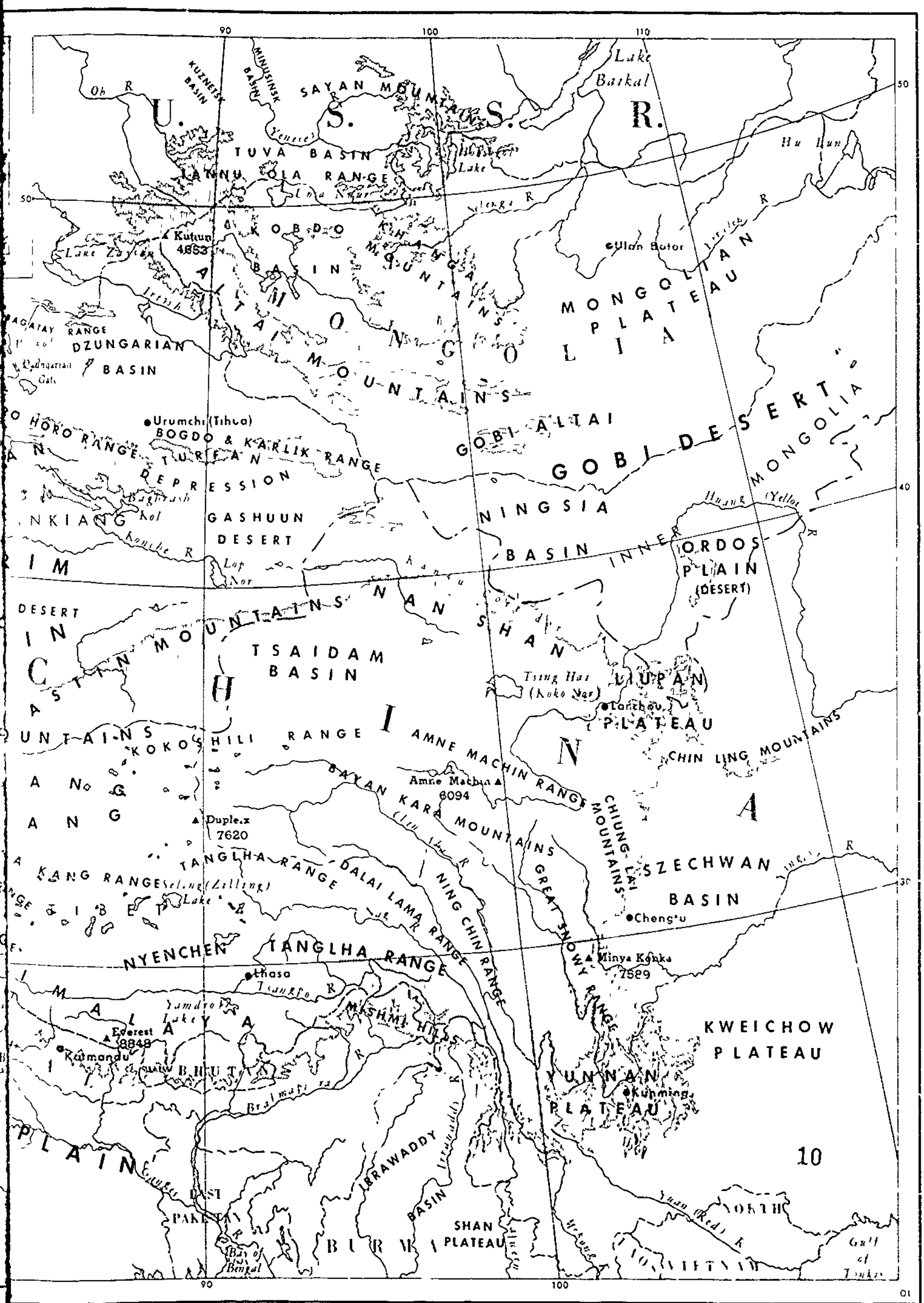

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SAYAN MOUNTAINS
Lake Baikal
KUZNETSK BASIN
MINUSINSK BASIN
TUVA BASIN
TANNU OLA RANGE
Hu Lun
Kutun 4653
KOBDO BASIN
CHANGAI MOUNTAINS
Ulan Bator
MONGOLIAN PLATEAU
ALTAI MOUNTAINS
MONGOLIA
Lake Zaysan
DZUNGARIAN BASIN
Urumchi (Tihua)
BOGDO & KARLIK RANGE
GOBI ALTAI
GOBI DESERT
INNER MONGOLIA
TURFAN DEPRESSION
GASHUUN DESERT
NINGSIA BASIN
Huang (Yellow) R.
ORDOS PLAIN (DESERT)
Lop Nor
NAN SHAN
TSAIDAM BASIN
Tsing Hai (Koko Nor)
LIUPAN PLATEAU
Lanchou
CHIN LING MOUNTAINS
CHINA
KOKO SHILI RANGE
AMNE MACHIN RANGE
Amne Machin 6094
BAYAN KARA MOUNTAINS
CHIUNG-LAI MOUNTAINS
Duplex 7620
TANGLHA RANGE
DALAI LAMA RANGE
NING CHIN RANGE
GREAT SNOWY RANGE
SZECHWAN BASIN
Chengtu
TIBET
NYENCHEN TANGLHA RANGE
Minya Konka 7589
Lhasa
Tsangpo R.
MISHMI HILLS
KWEICHOW PLATEAU
Everest 8848
Katmandu
BHUTAN
YUNNAN PLATEAU
Kunming
Brahmaputra
IRRAWADDY BASIN
EAST PAKISTAN
Bay of Bengal
BURMA
SHAN PLATEAU
Gulf of Tonkin
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INTRODUCTION

The purpose of this report is to present a survey of environmental conditions which might influence military personnel and materiel operating at high elevations in Central Asia. The study is primarily concerned with elevations in excess of 3,000 meters, where physiological problems among unacclimatized humans are likely to become acute. Even so, the entire highland area above 2,000 m is considered here because the decrement in unacclimatized human efficiency in the 2,000 to 3,000 m zone may be substantial enough to impair military effectiveness. Not infrequently the onset of debilitating symptoms of "mountain sickness" is experienced by new arrivals to this peripheral zone; indeed, there are on record cases of the very serious mountain sickness, pulmonary edema, at elevations as low as 2,500 m.

In Central Asia there are nearly a million square miles of upland above the 3,000-meter elevation, averaging close to 4,000 m overall. Excluding Antarctica, this represents about two-thirds of the world's area above 3,000 m or an area roughly one-third the size of the conterminous United States. It is a remote mountain wilderness which is difficult of access, sparsely vegetated, thinly populated, virtually devoid of any but very recent military roads or permanent communication lines, and extremely inhospitable due to its barren roughness and violent extremes of weather. Some 12 percent (approximately 125,000 square miles) is uninhabitable by reason of being permanently covered with snow and ice. At least an equivalent area is prohibitive to travel because of either its excessive mountaineering dangers or the fact that it lies above the limit where human acclimatization can still partially compensate for the oxygen deficiency, which is about 5,800 m.

The core of this vast mountain complex, comprising almost half of its total extent, is Chinese-occupied Tibet. Only five percent of this country lies below 4,000 m, which is approximately the upper limit of battalion-size training ever conducted by the United States Army. It is difficult to imagine a more inhospitable setting in which to conduct military operations. Nevertheless, intermittent conflict has occurred between Chinese and Indian forces along the Ladakh-Tibetan border since 1962. None of the action has taken place at elevations as low as 4,000 m, and outposts have been actively manned up to almost 5,800 m.

The Western scientific investigator has been afforded little access to the Central Asian Highlands beyond their southern periphery. In fact, much of the area is so remote and forbidding that many places had not been even superficially examined by any technical observers before the Chinese occupation of Tibet. Only in the last decade have appreciable areas been contour mapped to any reliable degree, thanks almost solely to photogrammetry of regions where aerial photography is the most difficult in the world.

INTRODUCTION

Army Field Manual FM 31-72, Mountain Operations (1964), sets forth standard military procedures for operating in mountainous terrain. It was developed over the preceding 23 years, initially from civilian sources, and later modified as a result of military experience at the Mountain Training Center (Camp Hale, Colorado) and its successors, the Mountain and Cold Weather Training Command (Fort Carson, Colorado) and the Northern Warfare Training Center (Fort Greely, Alaska). Virtually all of this Army experience was acquired with well-acclimatized troops performing at elevations below 4,000 m. Consequently there is little in this manual to suggest that acclimatization is really much of a problem.

While FM 31-72 is a practical and useful guide to field operations at moderate elevations, there is much that it does not warn about with respect to physiological limitations at higher elevations and the serious consequences of moving unacclimatized troops to emergency duty there. Neither does this nor any other Army service manual deal with the special operational and logistical problems which are unique to environments like those of the Central Asian Highlands. In a semi-technical manner, this study touches on most of these problems insofar as available data sources and English-language literature permit.

The bulk of the material presented here speaks indirectly to the specific problems, concerning itself rather with the applicable characteristics of the environmental envelope within which the mountain soldier must function. The terrain forms, surface climate, and vegetation are discussed in an introductory survey, beyond which further readings are suggested into the problems of local weather hazards, mountain sickness, soil trafficability, "nap-of-the-earth" aviation, thin-air ballistics, visual anomalies, high-elevation cooking, etc.

The report and the maps which illustrate it are organized according to a two-part concept of areal and thematic generalization. Part I deals with the entire area of the Central Asian Highlands and the several environmental aspects studied. Part II is more detailed and localized in its areal coverage. The illustrations for Part II consist chiefly of larger-scale mapping of four of the five sub-areas which are accorded separate discussion in the text. These were selected on the basis of probable military significance, with the intention of embracing most, if not all, of the distinctive environmental situations encountered throughout the Highlands.

Inasmuch as the literature on this part of the world is limited, it was often necessary to draw conclusions in part from highly generalized and incomplete mapping and from old observations of varying reliability. Every effort was made to qualify such judgments. A valuable source of information on environmental distributions is the Russian *Atlas Mira* (1964), particularly for supplementary information on soils, a subject which has been omitted from the present study.

PART I - OVERVIEW

1. PHYSIOGRAPHY

a. Landforms

The mountain and valley systems in the Central Asian Highlands serve as a barrier to communication, make climatic patterns complex, limit the number of people the area may accommodate, and curtail their activities. The direction of the gently arcing mountain systems is chiefly east-west, separating the Indian subcontinent from the rest of Asia and forming a natural barrier between China and the Soviet Union (Map 2).

The Tibetan Highlands make up the core of the Central Asian Highlands. Their southern border consists of the Himalayas, while the northern border is the Kun Lun Mountains (Map 3). The respective arcs of these bordering ranges diverge from their common, topographically congested western extremity at the Pamir-Karakoram region. From this western knot the Hindu Kush trends southwesterly through Afghanistan, while projecting northeasterly from the same knot is the Tien Shan. The Tien Shan borders the Tarim Basin on the north. The eastern end of the Central Asian Highlands takes a sharp southward turn as the Sino-Burmese Ranges.

The greater part of high Central Asia is composed of crystalline igneous and metamorphic rocks. Glacial sands and gravels form moraines and outwash terraces along drainage lines, particularly above 13,000 ft. Some parts of the Tibetan Highlands contain thick mantles of fine wind-blown silt derived from glacial outwash deposits. In general, unconsolidated materials are of greater military importance than solid rock, particularly with respect to vehicular mobility. Deposits of sand and gravel are valuable for construction; silts are not. Moreover, silts impose special peripheral problems when saturated or wind borne. Crushed limestone and marble, which are found in abundance nearly everywhere within the mountains, are valuable road-building materials. Clay deposits are not common, but during a wet period such an area, particularly one with steep slopes, could present serious problems to transportation.

Physiographically, the Central Asian Highlands consist of both glaciated and non-glaciated mountain ranges, arid high plateaus with glaciated mountains, and arid basins with interior drainage. The high valleys and passes, with elevations mainly above 3000 meters, have all been glaciated. Many still retain glaciers near their heads. The valleys and passes have typically U-shaped profiles and their floors are covered with gravel and sand. Many are flanked by nearly continuous terraces and exceedingly steep, barren slopes which are subject to avalanches and landslides. Because of great local relief, the valleys offer the only practical avenues of travel. Most trafficable passes are at 4,000 m or higher and are covered with permanent snow or large angular boulders. In general, the approach to the high passes from the south is much steeper than from the north.

The arid plateaus, principally the Tibetan Plateau, are broken by numerous snow- and ice-covered mountain ranges. In some parts of the same region there are depressions, some of which contain shallow salt lakes. However, neither the mountains nor lakes are extensive enough to preclude vehicular movement in any general direction.

Other arid basins with interior drainage include the vast Tarim Basin, occupied by the Takla Makan Desert and the Lop Nor salt flats. This basin is flanked by broad, dry aprons of alluvial debris transported by flash floods from the surrounding mountains. These aprons are broken by numerous deep, steep-sided dry washes. Travel generally is only practical along the valley floor or lower margins of these fans or aprons. A second major basin is the higher Tsaidam Basin, which, like the Tarim, is flanked by broad alluvial aprons. However, the Tsaidam Basin more closely resembles many playa basins in the United States in that much of its floor is occupied by large salt flats.

The unglaciated Lesser Himalaya, which receive the full impact of the monsoon, are deeply dissected by many V-shaped, boulder-clogged stream valleys. As in the Great Himalaya, passage through these ranges is practical only along a relatively few major valleys which are transverse to the structured trend. Great travel difficulty may be encountered because of heavy spring flooding and flash floods, narrowness of the valleys, and steep, heavily-vegetated side walls.

b. Glaciers

Throughout the Pamir, Tien Shan, Karakoram, Hindu Kush, and Himalayan mountain systems, over 6,800 square miles of snowfields and glaciers present additional hazards to men and materiel (Map 4). Mean climatic snowline ranges from just under 4,000 m (13,124 ft) in the Tien Shan to about 6,000 m (19,685 ft) in the western mountains of the Chang Tlang (Map 5), but valley glaciers drop down as low as 2,200 m (7,000 ft) in the Karakoram, 3,200 m in the Tien Shan and Nepal Himalaya, and 4,200 m in the Great Snowy Range.

Throughout most of the mountain systems the heaviest snowfall occurs on the high glaciers in July. Double maxima occur in June and September in the Sino-Burmese Ranges, and in March or April and again in August in Punjab and Kashmir. Following the snowy season, soft, deep snow lies on the glaciers. In addition to the difficulty of movement through the unsettled snow cover, crevasses are often bridged over and hidden from surface detection. Direct crossing of mountain glaciers by men is difficult and tiring at best. Direct vehicular crossing is in most cases not possible even for full-track personnel carriers.

Glaciers themselves impose special stresses at any altitude. The snouts of mountain glaciers in the zone of ablation tend to be nearly vertical (25 to 100 meters high or more), deeply crevassed, and, in some instances, covered with a coarse, uneven blanket of debris. Troops can often circumvent the terminus by moving along the sides, but here the confining walls may be bare rock, usually polished, with few hand- or foot-holds. Unless a glacier terminates in a relatively flat snout, which is more common in broad valleys, vehicular movement from the valley bottom onto the glacier is not possible. Once the glacier terminus has been ascended, crevasses provide a constant threat, as many are hidden by weak snow bridges. During the melt season, glacier surfaces may be covered by a foot or more of slush and criss-crossed by a complex network of deep, narrow ice valleys which, during the daylight hours, carry high velocity streams. It is well to keep in mind that all swift streams on the ice or in the proglacial zone can carry destructive rocks travelling unseen in the silty water. Huge boulders are rolled

along stream channels with tremendous force. Immersion in streams can result in severe chilling, icing and frost bite, or drowning; the smooth ice walls and high velocity of the stream provide little opportunity to gain hand holds, and many such streams plunge into deep crevasses. Such streams can provide insurmountable obstacles to vehicular movement because of their depth and vertical or nearly vertical wall angles.

Crevasses form in flexure bands across valley glaciers at the knick point where ice flows from one gradient to a steeper one. Here, so-called "ice falls" develop as a series of transverse cracks. Between the rows of crevasses a great deal of secondary jointing and toppling of ice walls leaves a jumbled maze of unstable pinnacles called seracs. These zones are generally hazardous even to trained mountaineers during the melt season (if any), extremely treacherous when covered with new-fallen snow, and totally impassable to vehicles.

Both axial and terminal moraines near active glaciers are likely to contain large cores of unmelted ice. The slopes of morainic ridges are generally quite steep (up to 36°), may have 100 to 200 m of local relief, and are covered with an unstable rubble of boulders and unsorted drift. Great care must be taken when crossing moraines because the rocks are sharp-edged and precariously seated. The rocks are damaging to footgear; other equipment can also be damaged if rubble suddenly slides off the side of a moraine.

c. Terrain and transportation routes *

The military importance of terrain hazards in the Asian Highlands is magnified by the existence of extremely long, slow surface supply routes. Areas of desert, badlands, dense rainforest, glaciers, snowfields, and high, alpine terrain are all extensive and locally severe.

Where the slope is reasonable and flanks are safe, snowfields can provide excellent avenues of travel at higher elevations. Lower down, valley glaciers may afford the only feasible passageways; however, such routes can impose formidable obstacles and special hazards to the movement of materiel. The dangers vary with the season because of snow accumulation and ablation.

* The inset to Map 4 shows many of the transportation routes mentioned in this section. However, this map was based on data compiled in 1951, and several important roads have been built since that time.

4

The problem of long supply routes is not easily solved in this part of the world. Aerial delivery of both materiel and personnel is difficult and often impossible because of one or more of the following local problems:

(1) Extreme mountain air turbulence
(2) Thick, persistent cloud cover
(3) Monsoon precipitation
(4) Precarious drop zones
(5) Lack of level space for pioneer heliports
(6) High elevation

With respect to helicopter operation, elevation is often the limiting factor. Most of the Tibetan Plateau, and indeed over 40% of the entire Central Asian Highlands, exceeds 5,000 m (16,404 ft) elevation. This is above the operational hovering ceiling of many military helicopters. The UH-ID "Iroquois" with 48-foot rotors can hover at about 5,550 m (18,209 ft) with full fuel load and a normal crew of three; however, the addition of 1/4 ton of cargo (less than 3 combat soldiers) reduces the hovering ceiling to about 4,600 m.

North of Tibet's Kailas-Nyenchen Tanglha mountain chain, the principal obstacles to vehicular movement (track or four-wheel drive) are the main mountain barriers. These are: Tien Shan, Alai, Altai, Muztagh Ata, Kun Lun, Hindu Kush, Karakoram, Astin Tagh, and Nan Shan. Elsewhere in these great, dry wastes, numerous basins separated by low divides provide generally good trafficability throughout the year, but wind, dust, desiccating heat, and lack of fresh water pose their own special threats to machinery. Poor trafficability is encountered in the loose sand of the Takla Makan and Gobi Deserts, and in locally swampy areas surrounding salt lakes in the Dzungarian Basin of Sinkiang and the Chang Thang of Tibet. The prime adversary of materiel here is abrasion. Dust and sand are constantly punishing fabrics, optical equipment, weapons, and machinery. Rough surfaces of loose stones and frost-shattered slates and shales are commonly encountered, and, in some areas, extensive lava fields must be crossed. The tactical necessity for defilade movement may impose the danger of rock slides and the difficulty of traversing loose scree slopes and cinder cones in the mesa and badland country of the Chang Thang.

In the Chang Thang most of the basins have only interior drainage, which produces many salt lakes and associated salt-pans. Salt dust, naturally wind-borne or disturbed by foot or vehicle passage, makes serious corrosive and abrasive problems for metallic hardware and motor carburetion. The lakes themselves may present local obstacles of considerable importance. Scores of salt lakes in the Chang Thang exceed 50 square miles, and nearly a dozen lakes in the south, both salt and fresh, cover 100 to 600 square miles each. The Na-mu Tsho (Tengri Tsho), 75 miles north of Lhasa, exceeds 1,000 square miles.

Fewer than a dozen all-season motorable roads pass entirely through the spines of all the major ranges in central Asia*. The following are noteworthy:

(1) Tezpur to Lhasa - Assam Himalaya (Bum Pass) - Maps 16 and 18
(2) Kalimpong to Lhasa - Sikkim Himalaya (Natu and Jelep Passes) - Map 18
(3) Katmandu to Lhasa - Nepal Himalaya (Kodari Pass) - Map 18
(4) Simla to Gartok - Kumaun Himalaya (Shipki Pass) - Maps 18 and 20
(5) Srinagar to Chushul - Punjab Himalaya & Ladakh Range (Zoji Pass and Chang or Bickey Pass) - Map 20
(6) Tun-huang to the Tsaidam Basin - Nan Shan (Tang Chin Pass) - Map 1
(7) Yarkand to Aksai Chin Basin - Western Kun Luns (Yangi Pass) - Map 20
(8) Frunze to Su-fu (Kashgar) - Western Tien Shan (Turug Art Pass) - Map 25

The 1950 Chinese invasion route into Tibet now has an all-season road from Cheng-tu to Lhasa via T'ing Ch'ing-to. This might also be considered to pass through a major range via the river gateway through the Great Snowy Range north of Minya Konka. Minya Konka towers to 7,589 m, but immediately to the north no other summits in the range reach 6,000m, and the river level in the gap is less than 2,000 m. All these routes follow stream valleys.

* See the larger scale sectional maps as listed for locations of these routes. There is no sectional map of the Nan Shan, but route (6) may be approximately located on Map 1.

There are a few other routes which may be traversed by jeep during the dry season, but, other than the ten routes mentioned above, all-season roads which are negotiable by passenger vehicles are confined to lower outlying ranges.

There are no railroads that significantly penetrate the high mountains, but two freight ropeways in the Lesser Himalaya are worth comment.

In Nepal a cableway starts at the Hitaura railhead (Map 18, at about 85° E 27° 30' N) and crosses 22 miles over the Mahabharat Lekh into Katmandu, carrying nearly all of the freight that enters the city. In Sikkim, a 42-mile cableway, with an interchange station at Gangtok, ties the Natu Pass frontier post to the West Bengal railhead below Kalimpong.

In the Lesser Himalaya, ridge lines are preferred as access routes. The crests of these ridges are rounded and undulating, and all are hard on footgear. Toni Hagen, the Swiss who completed Nepal's first Geological survey during the 1950's, wore out 40 pairs of sturdy Swiss-made climbing boots while hiking an estimated 9,000 miles. At 8 miles per day, a reasonable distance in the Himalaya, the attrition rate exceeded a pair per month.

Throughout the high ranges, travel on or off improved routes is confined to stream defiles and over rather high passes, many exceeding 5,000 m elevation. Most routes must cross and recross streams. Repeated immersion hastens the deterioration of clothing and footgear, rusting of metals, and frequently, ice-fouling of machinery. If vehicles are used, bridges must be built. At higher elevations (usually above 4,000 m) timber is unavailable, so most construction material must be carried with or ahead of the vehicles.

The deep incisement and narrowness of mountain valleys subject travelers to the sudden danger of avalanches, landslides, falling rock, and hostile attack from the flanking high ground. A military supply route, constructed by weeks of arduous effort, can be wiped out overnight by flash floods, landslides, or small-party demolition raids. The high ground on either side of valley routes seldom affords feasible paths for offensive flank patrols, but nearly always gives commanding observation and firing advantage to the defender with time to climb, select, and entrench.

In the Sino-Burmese Mountains, dense forests blanket extremely steep slopes. Excessive moisture, especially during spring and fall, softens the turf and encourages rank undergrowth. Most of this wilderness is a succession of closely spaced gorges of great depth, and the torrents which fill their bottoms sometimes render such routes impassable. Curiously, the lower slopes of the gorges are frequently denuded of growth by high water and land slumps. The stream margins afford the best, albeit hazardous, routes into the interior. Tree line is about 4,200 m in this area, so the ridges, which lie generally below this elevation, offer no routes through alpine meadows above the rainforest. Typically, the gorge slopes above the denuded band are dangerously steep, footing is treacherous, and fallen trees lie rotting in endless deadfalls to hamper movement and further restrict the poor horizontal visibility. Vehicular movement is impossible except in the very largest gorge bottoms. Until recently, only the Stilwell Road from Mandalay to Chungking afforded a dependable all-season motor route across the Sino-Burmese uplands, and this only traverses the less rugged parts of the Shan and Yunnan Plateaus.

Probably the most significant aspect of terrain, from the standpoint of stress on men and equipment, is its topographic roughness*. Crossing closely spaced, steep-sided interfluves requires considerable exertion by personnel, even when elevation is not a consideration. At high elevations (3,000 m and above), where physiological stress begins to be felt even on sedentary bodies, crossing such terrain with any degree of rapidity will result in extreme fatigue. Repeated closely spaced steep ascents and descents present a psychological problem to some people, namely, the disheartening prospect of "one more ridge". On the other hand, there could be some comfort to the soldier, under certain conditions, to be operating where there are no direct lines of sight from the enemy's position.

* Roughness, as used here, refers to the degree of dissection which any particular area displays.

The higher the hill and the steeper the slope, the greater will be the stress on an individual. To this must be added the stress of micro-relief. Micro-relief can take the form of hummocks, scree, talus, terracettes, or any other form which contributes to ground roughness (as opposed to topographic roughness). Micro-relief can be a hindrance as well as a help. The uneven footing adds to both physical and psychological stress, particularly in the tired person. Loose rocks in talus and scree deposits require extreme care with footing and the use of one or both hands for stability. Twisted and broken ankles are constant possibilities. On steep slopes (especially near the tree line transition) low vegetation obscures footing, adding to the difficulty of climbing. On the positive side, micro-relief can provide a degree of concealment both to an attacker and a defender.

Even where interfluves have gentle slopes or rise above timber line, large areas of loose boulder rubble may be encountered which require the same caution as talus. In these situations it will be difficult to keep a group of men together; even two men can become widely separated in traversing a slope with considerable and varied micro-relief. Each man must concentrate on his footing, which means that additional soldiers are required to maintain flank security.

Rescue operations, which will be required in some phase of mountain operations, cause great physical and physiological stresses. The effective rescue of even one man requires the assistance of at least two and usually more specially trained men.

Effective operation in mountain terrain, with all its physical, psychological, and mechanical stresses, requires a cadre of highly trained and motivated troops of above-average intelligence, who are equipped with materiel of special design.

2. VEGETATION

a. Military significance

Vegetation has significance to military operations in nearly any type of terrain. Its uses for concealment, fuel, and field construction are obvious, but a knowledge of the vegetation of an area may also be of local importance in selecting sites for air drops or landing strips, choosing foods for emergency survival, and avoiding plants containing contact poisons or unusual abrasive qualities.

In mountainous terrain, the importance of any of these aspects may be magnified by the nature of the operations and the unusual logistic problems that may exist. Supply difficulties may force an exceptional degree of reliance on improvisation with local construction materials and even on foods that may be locally available. Several other aspects of vegetation are peculiar to operations at high elevations. Mountain units may have to rely wholly on either aerial delivery or pack animals for supplies. Aerial delivery is facilitated by the presence of open, grassy areas free of trees or deadfall, yet all close support air operations in high mountains are hazardous. The use of pack animals renders the availability of forage plants important. Lack of motorized transport and the effects of elevation will increase the energy expenditure of troops, and therefore trafficability problems caused by density or other aspects of vegetation will be magnified. The possibilities of using vegetation as fuel will also have an increased importance in mountain or high-altitude areas both because of difficulties in supplying conventional fuels and the increased fuel requirements resulting from lower temperatures. Extra fuel may also be needed at high elevations to melt snow for water supply, and in certain systems for producing supplementary oxygen. Thus a knowledge of the vegetation in any mountainous area of potential operations may have a degree of importance exceeding that at lower altitudes.

b. Explanation of vegetation map

Owing both to the lack of detailed data for much of the area and the small scale of the accompanying map (Map 6), the numerous types of vegetation within the study area were consolidated into a few broad categories. It was first established that each category should have distinctive characteristics in relation to the various military aspects of vegetation discussed above. In addition, each should be extensive

enough within the study area to be mappable at a small scale (in our case approximately 1:9,500,000). On the basis of these considerations, five classes of natural vegetation can be distinguished at elevations above 2,000 meters in Central Asia. They are arranged below roughly in order of decreasing aridity:

(1) Steppe and Tundra
(2) Dry Forest and Woodland
(3) Thickets and Meadows
(4) Dense Forest, Evergreen or Mixed

Two other categories must be recognized that are not primarily natural vegetation. These are:

(5) Cultivated land
(6) Barren (vegetation very sparse or absent)

Cultivated land is found most commonly on river flood plains and much of it within the study area is irrigated. The "Barren" category includes areas that are covered by perennial snow or glaciers, or have a surface of bare rock, sand, gravel, or salt. Whatever vegetation exists in such areas is completely negligible as far as any military usefulness is concerned. They comprise all land higher than about 6,000 m and substantial areas at lower elevations where slopes are excessively steep or rainfall scant. Desert regions such as the Tsaidam Basin are largely barren but may have local areas of abundant vegetation where the water table is near the surface or the ground is watered by springs.

Variations in the vegetational pattern may result from differences in elevation, differences in exposure and soils, changes in precipitation caused by the presence of mountain barriers or varying distance from a moisture source, or differing degrees of human interference to which the vegetation has been subjected. In a mountain region, and especially one with the extreme degree of local relief found in much of Central Asia, these factors all may vary considerably within relatively small horizontal distances. A small-scale map, therefore, can only show the most widespread vegetation types and is of little use in representing the local diversity of vegetation.

Some idea of the difference in the amount of detail that may be shown at different scales can be obtained by comparing the small area in the Karakoram shown in Map 23a with the same area at a much smaller scale on Figure 6. Map 23a shows the elevational zonation of vegetation that is typical of this part of the study area but which cannot be adequately conveyed on a small-scale map. If sufficient data were available for preparing such maps for other parts of the study area, it is probable that equally complex patterns would emerge for much of the Himalaya, the Sino-Burmese Ranges, and parts of the Tien Shan.

c. Steppe and tundra

The most widespread category of vegetation within the study area is semiarid Steppe, with which is grouped the tundra or "arctic steppe" of the high elevations. Steppe, in the Western sense, may be defined as a treeless growth that does not cover the ground completely but has a substantial element of grass or grass-like plants. It may consist either of grasses (commonly bunch grass), sedges, forbs, low shrubs, or a combination of these. Although trees are absent in the typical form, there is a broad transitional zone between steppe and dry forest, in which an occasional tree is found on the margins of the steppe and the trees become increasingly dense with increasing elevation. The common Western usage followed here differs from that of the Russians who regard a "true steppe" as sod-covered (Berg, 1950). Nevertheless, some Russians have recognized a "desert-steppe" having a very thin herbaceous cover and scattered sagebrush (*Artemisia maritima* and similar species), which falls within the meaning of the word as used on Map 6.

Not only is steppe the most widespread type of vegetation in the area, but it also occupies the largest elevational range. It occurs over large areas at elevations below 2,000 meters (with which we are not concerned here) and extends upward above 4,000 meters.

Schweinfurth (1957) has distinguished the following types of steppe in the Himalaya: subtropical semi-desert, subtropical thorn steppe, artemisia steppe, and alpine steppe. Of these, only the last two occur at elevations above 2,000 m. In addition to artemisia steppe and alpine steppe, there are several types of "steppe forest". Although they have much in common with the typical steppe, they are here classified as Dry Forest because of the presence of trees, which constitutes a basic difference for military considerations.

Artemisia Steppe consists of a perennial cover of shrubs such as *Artemisia maritima, Eurotia ceratoides,* and *Kochia* sp., which cover from 50 to 70 percent of the ground surface and give the hillsides a "speckled" appearance from a distance (Schweinfurth, 1957). Between these shrubs there is a growth of annual grasses and herbs in late spring, chiefly in May and June, which dries up by July. They can be used as fodder during the growing period. Artemisia Steppe may be regarded as analogous to the Great Basin Sage formation of the western United States, which is also dominated by a species of *Artemisia.*

Alpine Steppe, which Schweinfurth equates with the "Alpine Tundra" of Ward (1936), is especially notable for its sparseness. Bare ground is conspicuous everywhere except in the valley bottoms. The vegetation typically is xerophytic, consisting of scattered thorn bushes, succulents on rocky slopes, cushion- and rosette-plants, and thin growths of grass. However, with increasing precipitation alpine steppe merges into moist alpine meadows, and there is no sharp line of demarcation between the two types at high elevations. The vegetative period extends from about June to September, but despite the meagerness of the growth it is grazed by sheep, goats, and yaks. Trees are present only in the valley bottoms, where willows, poplars, and various fruit and nut trees are maintained by natural streams or artificial irrigation. Irrigation permits cultivation of crops as well as raising animals and fruits within the regions of alpine steppe; the highest cultivated land reported in the Himalaya is in Tibet at 4,540 m (Schweinfurth, 1957). A large part of the Tibetan plateau, particularly the western half, has a vegetative cover of alpine steppe. There is a general decrease in precipitation from east to west in this region, causing a transition in vegetation from moist alpine meadows in the east to dry steppe in the west.

The line separating alpine steppe from barren ground is difficult to establish, because there are considerable local variations in the plant cover of high-altitude regions. Patches of mountain steppe or even alpine meadows may be interspersed among bare rocks and glaciers. Moreover, certain regions that are almost completely barren during much of the year may have a sparse cover of grass and other plants during the relatively short vegetative period. For military purposes, the most significant basis for distinguishing steppe from the "barren" type is whether it has enough vegetation to support pack animals for at least a part of each year. Without such vegetation, all supply would have to be either motorized (by surface or air) or by human porters.

d. Dry Forest and Woodland

This category includes a considerable variety of types dominated by various species of conifers and oaks, varying in density of canopy from very sparse to nearly continuous. All have in common, however, the fact that trees are not dense enough to offer a serious obstacle to movement. Only locally, as on sheltered, north-facing slopes, do the trees form dense stands, but these are exceptional and of only limited extent. Probably the most widespread tree of this category is the juniper, the commonest of at least seven species in the region being *J. semiglobosa*. This tree appears as isolated individuals in a transition zone from Steppe to Dry Forest, becoming gradually more dense until the typical Woodland formation appears.

The types of vegetation here grouped together as Dry Forest and Woodland are referred to by some authors as "steppe forest", because they generally combine an herbaceous ground cover with an open growth of trees. The steppe forests of the Himalaya and southern Tibet include the following types that have been distinguished on the basis of their dominant species and general elevational distribution:

(1) *Juniperus* spp. (2,000 to 4,000 m)
(2) *Quercus ilex* (900 to 2,700 m)
(3) *Pinus gerardiana* (1,900 to 2,700 m)
(4) *Quercus* species related to *ilex* (upper Tsangpo Valley 2,700 to 3,000 m and above)
(5) *Pinus tabulaeformis* and *Pinus armandi* (upper Tsangpo Valley and elsewhere in southern Tibet, 2,500 and 3,200 m)

In addition to these types, those listed below are often transitional between steppe forest and dense evergreen forest. They usually are open enough to be classified as Dry Forest, but under favorable conditions they may have more in common with Moist Evergreen Forest.

(1) *Pinus roxburghii* (generally below 2,000 m except in inner valleys)
(2) *Cedrus deodara* (pure stands in the inner Himalayas)
(3) Mixed deciduous and coniferous forests of the inner valleys of the Assam Himalaya (oak-pine-cypress forests, occurring up to 2,800 m)

(4) Mixed deciduous and coniferous forests of southeastern Tibet (spruce-birch forests in the Subalpine zone from 3,000 to 3,300 m)

[Dry Forest and Woodland can also be found in mountainous parts of the U.S.S.R. bordering the study area, both above and below 2,000 m.]

Where the rainfall is adequate (about 40 inches) the grass has a degree of luxuriance that requires its classification as meadow, but where it is drier there are true steppe forests. The forest trees tend to grow in isolated groves among the steppes and consist chiefly of deciduous trees and bushes. Fruit and nut trees such as wild apple, apricot, mulberry, and walnut, are especially abundant at lower elevations. As in the Himalayan region, juniper is a common component of these woodlands, but pine and oak are absent.

A distinctive type of dry forest that grows in dry basins of interior drainage is the tamarisk (*Tamarix* spp.). These trees obtain their water by deep tap roots that penetrate to ground water and therefore are not dependent on local precipitation.

Dry Forest and Woodland in the Central Asian Highlands may be important to military units both for pasture of pack animals and as sources for wood. Juniper, in particular, can be used as fuel; in many places it is the only natural fuel available. Fuel woods have already been considerably depleted by woodcutters in some places, so it should be recognized that supplies are not unlimited. In the oak woodlands local wood can be used for implements such as tool handles. The most valuable wood in the region is that of the deodar, which is used for railway ties, grape stakes, and construction. Cypress, which grows in the inner valleys of the Assam Himalaya, is used by the local people for shingles and prayer flag masts.

A number of trees within the Dry Forests, particularly at lower elevations, have edible fruits or nuts. *Pinus gerardiana* has edible nuts, and walnuts and pistachio nuts are common in part of the Tien Shan. Fruit trees such as apple, pear, plum, pomegranate, and almond are also common at lower elevations in the Tien Shan and sometimes appear above 2,000 m; apricots are grown in Tibet in the vicinity of Lhasa and to some extent at higher elevations. Such trees could be a partial source of food for small military parties, but they could not be depended upon for large units.

e. Thickets and Meadows

The essential characteristics of this category are the patchy nature of its woody growths and the relatively dense herbiage in its meadows. Stands of trees are neither continuous over large areas nor are they light and open as in the Dry Forests and Woodland. Precipitation is higher in Thicket and Meadow areas but the size and extent of tree growth is limited by the short growing season and low winter temperatures.

This category is found chiefly at high elevations in what are generally called the subalpine and alpine zones. The two are not differentiated because neither is sufficiently wide to be distinguished on a small-scale map. Moreover, there is no sharp line between them, since patches of forest extend up into the alpine zone in protected places while alpine meadows are scattered throughout the subalpine zone.

This type of vegetation extends from several hundred meters below the tree line to as much as a thousand meters or more above it. The tree line itself is not a sharp division between a zone of trees and one without trees, because of the interfingering of the two zones and also because there is a gradual decrease in the size of trees as tree line is approached. In the subalpine zone there are several successive associations with increasing altitude. In much of the study area the lowest is one dominated by birch *(Betula utilis)*. These are slender, deciduous trees or shrubs, often bent by the pressure of winter snow, with occasional conifers such as fir trees protruding above them. Trees that may occasionally be associated with birch are *Pinus excelsa* and various species of *Pyrus* and *Prunus*. Bark of the birch finds local uses as a roofing material, for packing, and even as a source of paper.

Rhododendron, of which there is a very large number of species in Central Asia, is found as undergrowth in the subalpine birch forest and as the dominant plant in the higher part of the subalpine zone. Between the upper and lower portions of this zone there is a mixture of birch and rhododendron, but with increasing elevation the birch disappears and stands of almost pure rhododendron are common. These are dense and almost impenetrable, forming a low evergreen forest of small trees or shrubs.

At the tree line these growths give way to low shrubs of the formation variously known as alpine tundra, alpine scrub, krummholz, or "high shrub-plains" *(Hochstaudenfluren)*. Krummholz is a growth of stiff evergreen bushes from 0.5 to 1 meter high, growing solitary or in a dense, continuous, recumbent mat interrupted by patches of meadow. The species comprising krummholz are often depressed forms of plants growing as trees or bushes at lower elevations. Typical of these are *Rhododendron* spp., *Juniperus squamata*, *J. nana*, and *Ephedra gerardiana*. Although low (ankle to waist high) and limited in extent, krummholz locally presents a considerable obstacle to movement due to its tough, tangled structure. On the other hand, it can provide small parties with fuel for cooking and warmth. Krummholz and meadows tend to intermingle above the tree line or to alternate according to exposure, the meadows occupying south-facing slopes and krummholz growing on the moister north slopes. Alpine meadows are characterized by grasses such as *Poa alpina* and *Festuca* spp., sedges such as *Cobresia*, and a variety of flowering annuals. They are important summer pastures at high elevations in central Asia.

f. Dense Forest, Evergreen or Mixed

This category includes all forests in the study area that are dense enough to have a continuous crown and an understory of shrubs or small trees. In the Himalaya such forests comprise mostly evergreen species, both broadleaved and coniferous, although the larch and some species of oak have a deciduous habit. In the eastern part of the study area (the western mountains of China proper) there is a more prominent deciduous element consisting of various species of familiar groups such as oak, birch, and maple.

In the southern part of the area Dense Forest tends to grow on south-facing slopes that are exposed to rain-bearing monsoonal winds, but farther north, in Tibet and Mongolia, it is more common on the moist northern sides of the mountains. Particularly in southeastern Tibet, it is difficult to represent their distribution on a small-scale map because the forests grow only on the shade slopes.

From the military point of view, the outstanding characteristics of these forests are the concealment that they afford and the difficulties they present to off-road movement. Following are the principal types within this category:

(1) Temperate mixed oak and coniferous forest. This is a mixed forest of evergreen oaks (*Quercus incana, Q. dilatata, Q. semicarpifolia,* in order of increasing elevation) and conifers such as the deodar and silver fir. *Rhododendron arboreum* is common in the understory. The conifers tend to avoid the south-facing slopes; oaks are less common on the northern slopes. These forests occupy low to intermediate slopes of the Himalaya between 1,800 and 3,300 m.

(2) Western Himalayan coniferous forest, also called the "*Pinus-Cedrus* formation" and the "belt of moist needle-leaved forests." It is a moderately moist forest dominated by conifers, particularly deodar, blue pine *(P. excelsa)*, spruce, and fir, with associated trees of maple, elm, walnut, ash, and other hardwoods. It grows to an elevation of 3,600 m on Nanga Parbat.

(3) Tropical evergreen upper montane broadleaved forest, also called temperate forest by many authors. It is a dense forest with trees up to 30 meters high in which mosses, epiphytes, and climbing plants are abundant. It includes a diverse flora, the dominant trees being various species of oak, magnolia, maple, and others. Rhododendrons are common in the upper part of the forest. Tree crowns are dense, fog is common, and undergrowth thick, making a forest which Champion (1936) described as "among the darkest and gloomiest in India." This type is found between 1,800 and 3,000 m, especially in eastern Assam and northern Burma. Bamboos grow in the lower part of the forest.

(4) Tropical evergreen Rhododendron-coniferous forest, or the "upper belt" of the tropical evergreen upper montane forest. Like the preceding type, it is often referred to as temperate forest. Its altitudinal range is from 2,800 to 3,600 (sometimes up to 4,000) m. Fog, which is very common in this zone, gives it a "cloud-forest" character. Hemlock is dominant in the lower part of the forest, giving way to fir above 3,000 m. Rhododendron is a conspicuous part of the understory throughout the forest. These forests are found eastward from western Nepal, along the south side of the main range of the Himalaya. They also occur in the valley of the Tsangpo, in the Mishmi Hills, and in the source region of the Irrawady.

(5) Eastern Himalayan coniferous forest, in continental interior valleys of the range, especially in Sikkim. Bhutan, and Monyal. It is a moderately moist forest dominated by larch, spruce, and hemlock, with an admixture of pine, fir, and juniper. Rhododendron is common in the understory. It grows in an altitudinal range from 2,700 to above 3,000 m; the highest reported stands are those of *Larix griffithii* at 3,800 m, just below the tree line in the drainage of the Shiar Khola (a tributary of the Buri Gandaki in north central Nepal).

(6) Northern coniferous forests, found on moist slopes of the Alai, the Tien Shan, and the Mongolian Ranges. They grow within the subalpine zone and tend to alternate with meadows occupying south-facing slopes. Locally the stands are dense and continuous enough to justify their classification as Dense Forest. Prominent species include the Tien Shan spruce *(Picea schrenkiana)*, fir *(Abies semenovii)*, and *A. sibirica)*, and larch *(Larix dahurica)*.

(7) Mixed evergreen-deciduous forests, growing extensively in the mountains of Yunnan and Szechwan where the terrain is too rugged for agriculture. These forests are a counterpart of the mixed forests of the eastern United States, where pines and hemlocks are interspersed among deciduous hardwoods such as oak, birch, and maple. At the higher elevations conifers predominate in China as in North America, but between 1,000 and 2,800 m the hardwoods are dominant, in some areas occurring in pure stands. Near settlements the forest has been cleared, but between villages it is dense and continuous.

3. CLIMATE

a. General

The Central Asian Highlands, because of their great elevation (2,000 to more than 8,000 m) and location (predominantly north of 25° N latitude), have a cool to cold mid-latitude continental climate with polar climates at the higher elevations. In this study, records from approximately 80 stations above 2,000 m (half being above 3,000 m) were considered (Map 7). A hypsometric map is used as the base for all climatic maps, and the elevation zones are shown in color to facilitate correlating the climatic data with elevation. In general, climatic isopleths are drawn at regular intervals and interpolations between stations are based primarily upon elevation. Although the density of stations

(about one for each 15,000 square miles) would not be too low for a lowland plain, it is inadequate for delimiting the local climatic differences in mountains. The understandable tendency to choose sites shielded from unfavorable weather probably explains much of the difference between surface-station and free-air measurements and the fact that the longer-period station observations indicate less severe conditions than do the accounts of explorers. Reliability of climatic data varies from station to station, dependent upon instrumentation and personnel, station exposure, and local terrain conditions.

Precipitation (Map 8) plays a very important role in the climate of the Central Asian Highlands, producing rainforests on the windward slopes of the southern and eastern borders of the highlands where the annual total exceeds 100 inches, and deserts in the high basins and ranges that have less than 5 inches annually.

In view of seasonal temperature variation, mean annual temperature is less useful than mean monthly temperature for a winter and a summer month. An indication of the annual range in temperature is given by Map 9, while Maps 10 and 11 depict the average temperature range in the coldest and warmest months, respectively. Since January and July are, almost without exception, the coldest and warmest months in the Central Asian Highlands above 2,000 meters, mean temperatures for these two months are shown on Maps 12 and 13. Isotherms below 40° F are not shown on the July temperature map because isolines around mountain peaks would be too crowded on a map of this scale. On the January map, isotherms below 0° F south of the 40th parallel, or -20° F north of that latitude, are not shown for the same reason. The diurnal range, although of similar magnitude, is frequently of greater importance than the seasonal range in its effects on men and materials.

These maps are supplemented by a classification map (Map 14), using the well-known Köppen classification (James, 1935). The classification criteria are summarized in Table I.

TABLE I

DEFINITION OF CLIMATIC CATEGORI
(Modified from Köpp

Symbols	Representative Climate	Representative Vegetation	Mean Temperatu Coldest Month
EF	Polar	(Snow Covered)	
ET	"	Tundra	
Df (a,b, or c)	Subarctic	Boreal forest	$<26.6°F$
Dw (a,b, or c)	"	" "	$<26.6°F$
Ds (a,b, or c)	"	" "	$<26.6°F$
Cf (a or b)	Humid Mid-Latitude	Mixed conifers, deciduous, and grasses	$<64.4°F$, $>26.6°F$
Cw (a,b, or c)	"		$<64.4°F$, $>26.6°F$
Cs (a or b)	"		$<64.4°F$, $>26.6°F$
BS (k or k')	Semi-arid	Steppe	
BW (k or k')	Arid	Desert	

a. mean temperature, warmest month, above 71.6°F
b. mean temperature, warmest month, below 71.6°F, with four or mor
c. mean temperature, warmest month, below 71.6°F, with one to thre
k. mean annual temperature below 64.4°F; mean temperature, warmest
k'. mean temperature, warmest month, below 64.4°F
x. maximum precipitation, spring, with C and D climates

*t is mean temperature in degrees Fahrenheit 13

TABLE I

CLIMATIC CATEGORIES IN MAP 14
odified from Köppen)

Mean Temperature Criteria		Precipitation Criteria	
Coldest Month	Warmest Month	Driest Month/Season	Annual
	<32°F <50°F, >32°F		
<26.6°F <26.6°F <26.6°F	>50°F >50°F	Non-seasonal In Winter, <0.1" wettest summer mo. In Summer, <1.6"+ <0.33 wettest winter month	>0.44t*-8.5 >0.44t-3 >0.44t-14
<64.4°F, >26.6°F <64.4°F, >26.6°F <64.4°F, >26.6°F	>50°F >50°F >50°F	Non-seasonal In Winter, <0.1" wettest summer mo. In Summer, <1.6" + <0.33 wettest winter mo.	>0.44t-8.5 >0.44t-3 >0.44t-14
	>50°F	Summer, 70% in coldest six months Winter, 70% in warmest six months Non-seasonal	 <0.44t-14 <0.44t-3 <0.44t-8.5
	>50°F	Summer, 70% in coldest six months Winter, 70% in warmest six months Non-seasonal	 <0.22t-7 <0.22t-1.5 <0.22t-4.25

ith four or more months with mean temperatures above 50°F
ith one to three months with mean temperatures above 50°F
rature, warmest month, above 64.4°F

ates

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b. Barometric Pressure

Elevational differences exert a strong influence on climate in mountainous areas. Atmospheric pressure decreases rapidly with increasing elevation, and the partial pressure of the oxygen in the air changes in proportion to the change in the total atmospheric pressure. The resulting oxygen deficiency creates great physiological stress on man.

The change of pressure and temperature with height, standardized for the average atmosphere at 45°N Latitude (US Air Force Cambridge Research Laboratories, 1965) is shown in Table II.

TABLE II. Average Temperature and Pressure at Various Altitudes, Standard Atmosphere at 45°N

Height (m)	Temperature (°F)	Pressure (mb)
0	59.0	1013.3
500	53.2	954.6
1000	47.3	898.8
1500	41.5	845.6
2000	35.6	795.0
2500	29.8	746.9
3000	23.9	701.2
3500	18.1	657.8
4000	12.2	616.6
4500	6.4	577.5
5000	0.5	540.5
5500	-5.3	505.4
6000	-11.0	472.2
6500	-17.0	440.8
7000	-22.8	411.1
7500	-28.7	383.0
8000	-34.5	356.5
8500	-40.3	331.5
9000	-46.2	308.0

The average level above which the pressure is half that at sea level is about 5,700 m. Pressures at a particular elevation tend to be higher in the warmer season and in the warmer regions south of 45°N Latitude, and conversely, lower in the colder season and in colder regions to the north (US Air Force Cambridge Research Laboratories, 1965). Although

the absolute value of the pressure change with height is less at high altitude, it is a slightly larger percentage of the total pressure at that altitude. For example, the difference in the pressures between 8,000 and 9,000 m is 14% of the pressure at 8,500 m, while the difference between 1,000 and 2,000 m is 12% of that at 1,500 m.

The elevation at which marked symptoms of mountain sickness usually appear is 3,500 m in temperate regions and higher in the tropics, but it can vary with the individual from 1,500 to 6,000 m (Bert, 1943). (See Appendix A for description of symptoms). The variation among individuals in response to lowered pressure and with degree of acclimatization of a particular individual results in differences of opinion regarding a critical minimum elevation necessary to produce symptoms and also overshadows day to day changes of pressure at a particular elevation. Speaking of the Ladakh area, Hall, Barila, Metzger, and Gupta (1965) mention 1,830 m as the lower limit for acute symptoms in some individuals.

Pressure changes resulting from increase in elevation are much more important than variation at a single station or level. Observations of extreme pressures at high stations in Central Asia appear to be non-existent, but their estimated range at 4,500 m is less than 75 mb (i.e., less than an elevational change of 1,000 m). For the same pressure change the elevational range becomes less below this height and greater above this height, but it is estimated as less than 1,500 m at 8,000 m. These estimates are based upon free air soundings (Bryson et al., 1965).

Data for twelve stations below 2,000 m in northern India (India Meteorological Department, 1891-1954) showed a maximum range of 40 mb, which would be equal to the difference of pressure within about 525 m at 4,500 m. Data for longer periods presented for U. S. stations (Ludlum, 1955) show largest ranges where stations are exposed to intense coastal storms and hurricanes. Transposing pressure ranges from sea level to high altitude is of questionable accuracy, however, and application to a single station of the range between a pressure minimum experienced in a hurricane and a maximum in an intense continental anticyclone is particularly unrealistic for Central Asia.

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Some observed variations of pressure above 4,000 m are shown in Table III. Those at 1,000 m intervals are from aerological soundings near Pamirski Post (Belinskig and Khromov, 1963). The others are from the Everest area: at 5,121 m (Ruttledge, 1934); at 5,486 m, Base Camp (Pugh, 1957); and at 5,800 m, Silver Hut (Pugh, 1962).

TABLE III. Observed Variations of Pressure Above 4,000 Meters

Ht. (m)		Length of Period	Pressure Variation (MB)	Approx. Alt. Equiv. (m)
4,000	Jul-Sep (1957-9)	9 mo.	13	162
4,200	Jun-Sep (1958)	4 mo.	17.2	214
5,000	Jul-Sep (1957-9)	9 mo.	23	320
5,121	17 Apr-early Jul abt.	3 mo.	8	110
5,486	May 1953	11 days	6	88
5,800	21 Jan-23 Mar 1961	55 days	14.6	220
6,000	Jul-Sep (1957-9)	9 mo.	13	200
7,000	Jul-Sep (1957-9)	9 mo.	28	484
8,000	Jul-Sep (1957-9)	9 mo.	35	680

While there are no long-period data from the Central Asian Highlands to show the seasonal or elevational variation of the absolute extremes of pressure (which may follow a different pattern from that of monthly means), monthly means for stations below 4,000 m indicate:

(1) Near 2,000 m, maximum pressure in winter, with increase in the pressure difference with season from southeast to northwest in the Highlands.

(2) In the 2,000 to 3,500 m range, decreasing pressure difference with season and appearance of a secondary oscillation with minima in summer and winter and maxima in spring and fall.

In addition, free-air data from mid-latitudes indicate that the size of the pressure range increases directly with altitude from a minimum near 3,000 m to a high-elevation maximum near 8,000 m.

The few stations for which pressure normals are available are listed with their elevations in Table IV. Most of the normals are for 0800 and may, therefore, be a few tenths of a millibar higher than the 24-hour normal.

TABLE IV. Pressure Normals at Stations in Central Asia

Ht. (m)	Pressure (MB)	Station (& no. of yrs.)	Ht. (m)	Pressure (mb)	Station (& no. of yrs.)
478	960.8*	Tashkent (65)	1727	828.2	Gangtok
841	920.5*	Alma-Ata (20)	1729	827.0	Parachinar
1208	878.8	Kalimpong (20)	1893	810.1	Kunming (19)
1302	868.3	Cherat (45)	2017	799.5	Kalat (20)
1435	848.6	Drosh	2049	797.4	Naryn (10)
1490	851.0	Gilgit	2115	789.8	Mussoorie (10)
1500	849.1	Shillong (48)	2149	786.5	Chakrata (12)
1587	843.2	Srinagar (50)	2168	783.7	Murree (50)
1601	832.2	Quetta (69)	2204	780.6	Simla (70)
2265	775.8	Darjeeling (50)	3074	702.5	Kyelang (4-5)
2280	765.3**	Kunming (2)	3514	666.2	Leh (69)
2288	774.7	Skardu	3685	629.8	Lhasa (5)
2314	771.8	Mukteswar (40)	4610	580.5	Hanle
3066	704.4	Dras			

* 3 or 4 times a day
** hourly

Pressure observations above 4,000 m are scarce. Short-period records are available from the stations shown in Table V. The pressure observations shown from the Everest and Minya Konka regions are single observations or averages of observations on a few days only.

TABLE V. Pressure Observations at Stations Above 4,000 m

Height (m)	Pressure (mb)	Location	Month and Year	Period (days)	Reference
4196	615.8	Upper Yulong (Minya Konka)	Jul 1932		Burdsall, 1935
4200	619.5	Kara-Dzhilga-Kry	Jun-Sep 1958	105	Tadzhikov, 1963
4394	600.9	Base Camp (Minya Konka)	Oct 1932		Burdsall, 1935
4549	595.0	Sta.G (Minya Konka)	Aug 1932	26	Burdsall, 1935
4600	586.6	Mingbo Camp (Everest)	Jan-Mar 1961		Pugh, 1962
4660	589.9	Tsemei La (Minya Konka)	Aug 1932		Burdsall, 1935
4724	566.6	Chule (Everest Region)	May 1933		Pugh, 1957
4781	579.4	Djezi La (Minya Konka)	Jul 1932		Burdsall, 1935
5121	541.2	Everest	Apr-Jul 1933	abt 85	Ruttledge, 1934
5362	535.2**	Depsang	Jul 1914	31	Allesandri, 1931
5486	529.3	Base (Everest)	Apr-May 1953	11	Pugh, 1957
5510	528.8	Camp I (Minya Konka)	Oct 1932		Burdsall, 1935
5800	506.6	Silver Hut (on Ama Dablum)	Jan-Mar 1961	55	Pugh, 1962
6096	493.3	Manlung La	May 1933		Pugh, 1957
6248	486.3	Camp III (Everest)	May 1933		Pugh, 1957
6400	458.6	Camp III (Makalu)	Apr 1961		Pugh, 1962
6462	462.6	Camp IV (Everest)	May 1933		Pugh, 1957
6858	449.3	Camp V (Everest)	May 1933		Pugh, 1957
6919	453.3-445.3	Greene's Camp (Everest)	May 1933		Pugh, 1957
7315	410.6	Camp VII (Everest)	May 1933		Pugh, 1957
7430	400.0	Makalu Col	Apr 1961		Pugh, 1962
7830	384.0	Camp VI (Makalu)	May 1961		Pugh, 1962
7833	406.6*	Greene's Camp (Everest)	May 1933		Pugh, 1957
8848	333.3**	Summit (Everest)	May 1953		Pugh, 1957

* Hourly observations

** Assumed to be very close to actual figures although only temperature was measured at the summit while temperature and pressure were being observed at Camp VII, 7,315 m (Pugh, 1957).

c. Precipitation

Precipitation in mountains is influenced by change in elevation through the forced ascent of moist air. The Central Asian Highlands present a physical barrier to the wind circulation. They are exposed on the east to the northeast monsoon of China, on the south to the southwest monsoon of India, on the west to cyclonic disturbances from the Mediterranean or Atlantic, and on the north and northwest to cold air from the arctic regions. Where this air is first lifted by outlying ranges or the lower parts of high mountain ranges, precipitation amounts on the windward slopes increase with elevation. In Central Asia, the maximum rainfall occurs just below 2,000 m (Dhir and Singh, 1953), with considerable decrease above 3,000 m (Fig. 8).

Availability of moist air and the nature of the general wind circulation are primary determinants of quantity and distribution of precipitation. Where the moisture source is closer and warmer, as in the case of the monsoons, heavier precipitation is received as the highlands force the air to ascend. Precipitation is usually, although not always, greater on windward slopes than on leeward. Quantitative differences are seldom known, but are so great that they cannot be shown by isohyets except on large-scale maps.

In the areas where the moist air of the Indian monsoon first rises up the slopes, heavy precipitation is the climatic element producing the greatest stress on men and materials. Precipitation averages along the southern Himalayan slopes, as given by Waddell (1899), Dhar and Narayanan (1965), Pugh (1952), and Müller (1958), are shown in Table VI.

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TABLE VI. Mean Annual Precipitation, Southern Slope of Himalaya

Station	Height (m)	Mean Annual (inches)
Mt. Everest	5800	18
Sonamarg	3560	71
Mt. Everest	3350	37
Walungchung Gola	3165	40
Yatung	2987	57
Mt. Everest	2750	90
Gurais	2640	49
Ft. White	2365	127
Darjeeling	2265	122
Pedong	2000	103
Sinlumkaba	1829	171
Gangtok	1725	146
Shillong	1500	103
Kurseong	1400	166
Sadon	1396	120
Cherrapunji	1314	425
Siliguri	125	123

Although the precipitation maximum occurs just below 2,000 m, widespread glaciation seems to indicate heavy snowfall at high elevation (Map 4). However, little water content is required to balance a relatively small loss by ablation, and recent studies confirm the precipitation decrease at higher elevations in the Himalaya.

Chinese snowfall observations (Chung-kuo Ch'i-hou T'u, 1960), and data from other sources for three additional stations, are given in Table VII.

TABLE VII. Snowfall at Chinese Stations

	Elevation (m)	Snowfall No. of days	Accumulation No. of Days	Accumulation Max Depth (in.)
Hsi'ning	2380	50	-	-
Sung-pan]	2856	40	52	4
Hua'chia'ling	2440	36	63	4
Hua-shan	2074	26	82	11
Min-hsien	2246	24	20	3
Kang-ting	2558	21	-	-
Hsiao-chin	2465	8	5	2
Ta-li	2001	2	0	0
Li-chiang	2416	2	0	1
Huang-ho-yen	3873	86	106	4
Wu-hsiao-ling	3045	75	124	9
Omeishan	3358	72	117	8
Yu-shu	3873	45	-	-
Kan-tz-zu	3320	34	42	6
Kung-ho	3105	18	24	3
Chang-tu	3200	18	16	4
Lhasa	3685	8	-	-
Tu-lan-ssu	3075	7	-	-
Zhikatse (Yusov)	3660	5-6	-	8-11
Ta-jih (AWS)	3600	50-125	-	-
Hsia-ho (AWS)	3049	50-125	-	-

The fact that another author (Yusov, 1958) gives two snowfall-days for Chang-tu emphasizes the fact that these are short-period records, and also that the definition of a snowfall-day may vary.

In general, there are less than 20 snowfall days in the Tsaidam Basin, in the valley of the Tsangpo in the lee of the Himalaya, and in the lower elevations of the Sino-Burmese Ranges. The first of these is an example of control by aridity, the second by shielding, and the third by a winter-dry precipitation regime. Where there is less control by any of these factors, the number of snowfall days increases into the range of 20 to 50 days per year. More than 50 snowfall days occur in exposed

locations near the headwaters of the large rivers (Salween, Mekong, Yangtse, and Huang), or where high latitude and/or elevation results in the monsoonal precipitation falling as snow.

In the cold, dry regions with little cloudiness, such as the eastern Pamirs and the Chang Thang (northern Tibetan Highlands), snow cover disappears rapidly. There is great variability in precipitation, dependent upon the degree of penetration of the monsoon. Large areas of steppe and even desert climate occur in the highlands.

Apart from the monsoon rains and the more vigorous storms that reach the borders of the highlands, precipitation, as in other mountain areas, results from convection during daytime heating and shows a fairly regular diurnal pattern which is most pronounced in the areas of greatest relief and available moisture. Mornings are generally clear, cool, and calm until about 0900 or 1000 hours, with convective clouds building up during the late morning. Sometimes showers occur by noon, continuing intermittently through the afternoon, and occasionally into late afternoon. Winds diminish and clearing occurs slowly late in the day. At the highest elevations, a second wind maximum occurs at night. Rain may be heavy in the wetter regions of the main mass of the highlands, but in much of the region, water content is low. The diurnal pattern is more pronounced in the warmer season but is still apparent in the colder months.

Storms are sudden and violent throughout the mountains of Central Asia. Although the yield of precipitation is less in the more arid highlands, abrupt onset and strong wind gusts are characteristic (Hedin, 1909). Observations that show low visibility less than 1% of the time in the Tibetan Highlands (U.S. AWS, 1945) give no indication of the suddenness and extent of visibility restriction in the thunderstorms or snow squalls.

Thunderstorms are frequent and severe in the dissected ranges of the Chinese border provinces (Hanson-Lowe, 1941), the Himalaya (Wager, 1934), and in the western Tien Shan and the western Altai (Arkhipova). They are often accompanied by destructive hail, particularly in the western Lesser Himalaya with 16-20 days/year (India Meteor. Dept., 1953); and in the western Tien Shan, 6-11 days/year (Pastukh and Sokhrina, 1960). Hail frequency increases rapidly with height up to 2,000 or 2,500 m, but only slightly above that elevation. In the upper parts of the gorges of the large rivers in the Chinese border provinces there may be more than 80 thunderstorm days per year (Hushu has 86; Patany, 85; Kantzu, 81).

Most of the year's precipitation, which totals less than 30 inches at each of these three stations, falls in summer thunderstorms. Longer record stations in the Western Himalaya show: Murree, 73; Mussoorie, 60; and Simla, 40 thunderstorm days. Even such sheltered locations as Lhasa and Srinagar have 53 and 54 thunderstorm days, respectively.

d. Temperature

The temperature regime above 2,000 m ranges from a polar climate on the exposed high plains and peaks, with no months averaging above freezing, to a warm temperate climate in lower sheltered locations such as Kalat, Khorog, and Skardu where the warmest month averages as high as 70° F. Temperature in mountains normally decreases with increasing elevation, but not as uniformly as does barometric pressure. Mountain peaks and other sites exposed to winds resulting from the general circulation, rather than from the influence of the local terrain, will have temperatures nearest those of the free air. Above 2,000 m the normal temperature lapse rate in all seasons averages about 10-11°F (5.5-6.0°C) degrees per 1,000 m, except in shielded basins and valleys where lower level inversions may occur on clear nights.

Truly reliable mapping of isotherms in mountains would require well established temperature lapse rates and station normals for every range and valley with adjustments for slope exposure, varying types of vegetation cover, and extent of snow cover. While a few detailed studies of temperature gradients have been made in the Central Asian Highlands, it is not possible to apply these apart from the locales where they were measured.

Temperature decreases northward about 1 F° per degree of latitude in mountainous regions annually reached by the Indian monsoon (north to about 30°N), and approximately 1.5 F° per degree of latitude farther north. The range between the warmest and coldest months (Map 9) is large and increases northward and westward.

The diurnal temperature range varies considerably from region to region. On the southern Himalayan slopes high humidity, frequent fog, and persistent cloudiness in the wet season modify the mean temperature and the daily temperature range. The diurnal temperature range is low in the Chinese, Burmese, and Indian lowlands, and in Kashmir in both winter and summer (Maps 10 and 11). The daily range is large in interior

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shielded valleys at such stations as Lhasa, Zhikatse, and Gyangtse, and in the east at Sungpan and Patang both summer and winter. Largest ranges in summer occur in Afghanistan and the southern Pamirs in the 2,000 and 3,000 m zone. These ranges are similar to those in the interior basins such as the Tarim, Tsaidam, and Dzungarian.

The atmospheric disturbances that reach the western borders of the highlands in winter and spring produce cloudiness which reduces the January diurnal temperature range in the western Pamirs and Tien Shan. In the Altai, precipitation and cloudiness produce lower ranges in the northern and western parts, while ranges are larger under clear skies in the southern and eastern parts. The average daily range does not fully express the extremes that may be experienced. Diurnal changes of 50° F frequently occur. Kobdo, located in a basin and subject to foehn winds, has experienced rapid temperature rises of 40 F° with relative humidity falling from 35 to 11% (Murzaev, 1950). Fluctuations of 10 F° may occur several times within a few hours. In the high Pamirs a 60 F° fall in temperature in a few hours overlapping the time of sunset was reported by Olafsen in 1903.

Nighttime loss of heat by long-wave radiation to outer space under clear skies results in temperature inversions; these inversions may be very intense in enclosed mountain valleys where they are enhanced by cold, dense air-flow down the slopes. While some of the lowest temperatures in mountains occur on the highest summits, minima of equal severity occur in enclosed basins and valleys that collect the cold air. Such valley minima, however, occur under calm conditions, and cooling power is not high. The literature contains references to expedition minima of -40°F at Lake Aksai Chin (Hedin, 1909), -67°F at Nagchu near Adag Mamar (Roerich, 1931), -49°F on Mt. Stalin* (Romm, 1936), -54°F near Pamirski Post (Olufsen, 1903), and, at longer-record stations, -50°F at Pamirski Post and -49°F at Dras (India Meteor. Dept., 1953). Temperatures lower than -60°F occur below 2,000 m in Outer Mongolia and in Siberia.

e. Wind

In general, wind patterns below 5,000 m in the Highlands are governed, not by general circulation, but by local mountain and valley topography as well as by the resulting distributions of radiation, temperature, and pressure in these regions. The subjects of mountain and katabatic winds are complex and only now are coming under intensive study.

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* Now Pik Kommunisma

Like temperature, wind and cloudiness exhibit a characteristic diurnal regime in mountains, with maxima occurring in the afternoon. Unequal surface heating by the sun, producing upslope or downslope winds, becomes more evident on steeper slopes and with lower sun angles. The unequal heating is more pronounced in winter and in higher latitudes.

The mountain-valley wind phenomenon, so prevalent in varying degrees throughout the highlands, is based on the principle that, during nighttime, the colder, denser air drains down the slopes and accelerates down the axis of the valley. Studies in the Alps show this "mountain wind" strengthening to 8 knots by morning (Defant, 1951). Within the hour after sunrise, air begins to warm and rise up the slopes, rising more rapidly on south-facing slopes. By mid-morning it retreats up the valley axis and side slopes so that by the time of maximum heating an up-valley wind is produced which is usually stronger (11 knots in the Alps) than the early morning "mountain wind." Within the hour after sunset, air begins flowing down the slopes again. The valley wind subsides and gradually reverses direction becoming a "mountain wind" late in the night. Wind speeds usually reach a maximum in the afternoon except on the high peaks where they are consistently strong. In locations subject to mountain-valley winds, the "mountain wind" often attains a secondary maximum at night, which tends to pulse in short-period gusts.

Valleys with cloud banks and damp forests on their sides, found in moist areas of the eastern Himalaya, frequently have dry bottoms due to complex mountain-valley wind circulations (Schweinfurth, 1956). The glacier wind is a shallow down-valley flow occurring by day as well as at night on either clear or cloudy days. It may flow under the up-valley wind by day and strengthen the mountain wind at night.

Exposure to or shielding from the wind are of great importance in terms of human comfort, particularly at high elevations, since increase in the wind speed has a greater effect in increasing the cooling power than does decreasing temperature. A wind speed of 39 knots is the maximum recorded at a regular observing station on the Tibetan Plateau; however, in this high basin-and-range region there is little natural shelter from the wind. On Ama Dablum, near Mount Everest at 5,800 m, a maximum of 35 knots and gusts up to 60 knots have been recorded (Pugh, 1962). In general, high winds occur by day while lowest temperatures occur on clear, calm nights. In high passes winds are funneled through the gaps, and temperatures in winter are near zero in daytime. Bent trees with sparse growth on their windward sides are indicative of the strong prevailing wind; hence there is a probability of extreme wind-chill in such locations.

f. Solar Radiation

Few measurements of solar radiation are available, and they were taken with various types of radiometers. Observations taken by several high-altitude scientific expeditions are summarized in Table VIII.

The sites possessed different characteristics. At Depsang the presence of dust in the atmosphere limited good observing conditions. It would be expected that the global radiation total at the glacier sites, both in the Karakoram (Chogo Lungma Glacier) and in the Everest region (Khumbu Glacier), would be lower compared with that at the high

TABLE VIII. SOLAR RADIATION IN THE HI
(Langley (ly) = gm

Type	Elev. (m)	Location	Date	No. o Days
Direct (normal incidence)	4200	Kara-Dzhilga-Kry Eastern Pamirs 38°N	July 1958	
(hor. surf.)	5362	Depsang (Maps 7, 18 & 20)	July & Aug	10
(normal incidence)	5718	Silver Hut on Ama Dablum near Mt. Everest - Map 17)	26 Apr. -12 May, 1961	4
(hor. surf.)	6400	K-2 (Camp III) Karakoram (Maps 3 & 19)	7 July 1955	1
Global	1587	Srinagar	Jan July	
	4000	Glacier, Everest (Maps 3 & 17)	10-16 June 1955	7
	4300	Chogo Lungma (near Malubiting Peak 35N/T5E - Map 19)	12 July	22
	4300	Glacier, Everest (Maps 3 & 17)	29 July 1955	1
	4900	Fedchenko Glacier, Pamirs (Map 19)	June	1
	5718	Silver Hut on Ama Dablum (near Mt. Everest - Map 17)	26 Apr 12 May 1961	8 22
	6400	K-2 (Camp III) Karakoram (Maps 3 & 19)	7 July 1955	1

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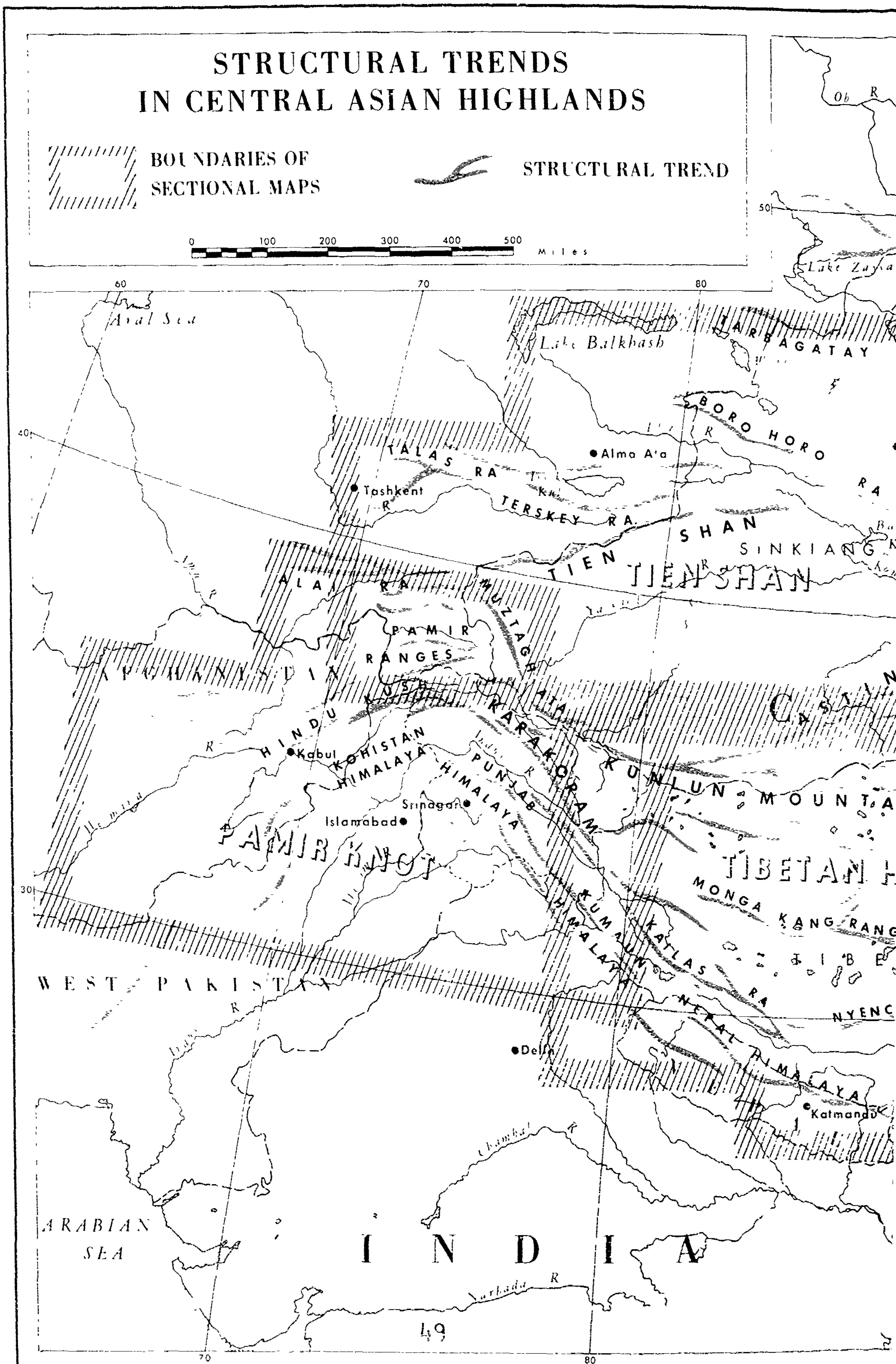
locations in the Karakoram (K-2) and the Everest area (Silver Hut), due to horizon obstructions and atmospheric filtering, particularly by the water vapor produced by great ablation. However, it was concluded that on the Khumbu Glacier solar radiation reflected from higher snow slopes and glaciers may augment the sky radiation portion of the global by 20 to 30% (Bishop, 1965). This also is indicated by the relatively high fraction of the diffuse radiation (about 10% that is in the infrared heat-energy range. The yearly total of global radiation observed on the Fedchenko Glacier (38°N, 4,900 m) is among the highest on record (Geordio, 1961).

DIATION IN THE HIGH MOUNTAINS OF CENTRAL ASIA
Langley (ly) = gm cal/cm^2)

Date	No. of Days	Reference	ly/min	ly/day	Remarks
July 1958		Tadzhikov 1963	1.74		Max at noon
July & Aug	10	Alesandri & Venturi-Ginori 1931	1.56		Mean at noon clear
26 Apr. -12 May, 1961	4	Bishop, et al 1965	1.53		11 series, clear Max-165 ly/min
7 July 1955	1	Untersteiner 1958	1.65		Abt. 1130 clear Instantaneous
Jan July		Ramdas 1956		319 690	Clear
10-16 June 1955	7	Untersteiner 1958	2.36		Max. 1330H 9/10 cloudiness
12 July	22	Untersteiner 1958		728	Hourly, variable cloudiness
29 July 1955	1	Untersteiner 1958	2.36		Max. 1330H 9/10 cloudiness
June	1	Geordio et al 1961		865	Max. day
26 Apr 12 May 1961	8 22	Bishop et al 1965	1.55		18 series, clear
7 July 1955	1	Untersteiner 1958	2.6		Max abt 1130 9/10 cldns.
	20				


STRUCTURAL TRENDS
IN CENTRAL ASIAN HIGHLANDS
BOUNDARIES OF SECTIONAL MAPS
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Aral Sea
Lake Balkhash
Lake Zaysan
TARBAGATAY
BORO HORO
Alma Ata
Tashkent
TALAS RA
TERSKEY RA.
TIEN SHAN
SINKIANG
ALAI RA
MUZTAGH ATA
PAMIR RANGES
AFGHANISTAN
HINDU KUSH
KARAKORAM
KOHISTAN HIMALAYA
PUNJAB HIMALAYA
Kabul
Srinagar
Islamabad
PAMIR KNOT
KUNLUN MOUNTA
TIBETAN
MONGA KANG RANG
KUMAUN HIMALAYA
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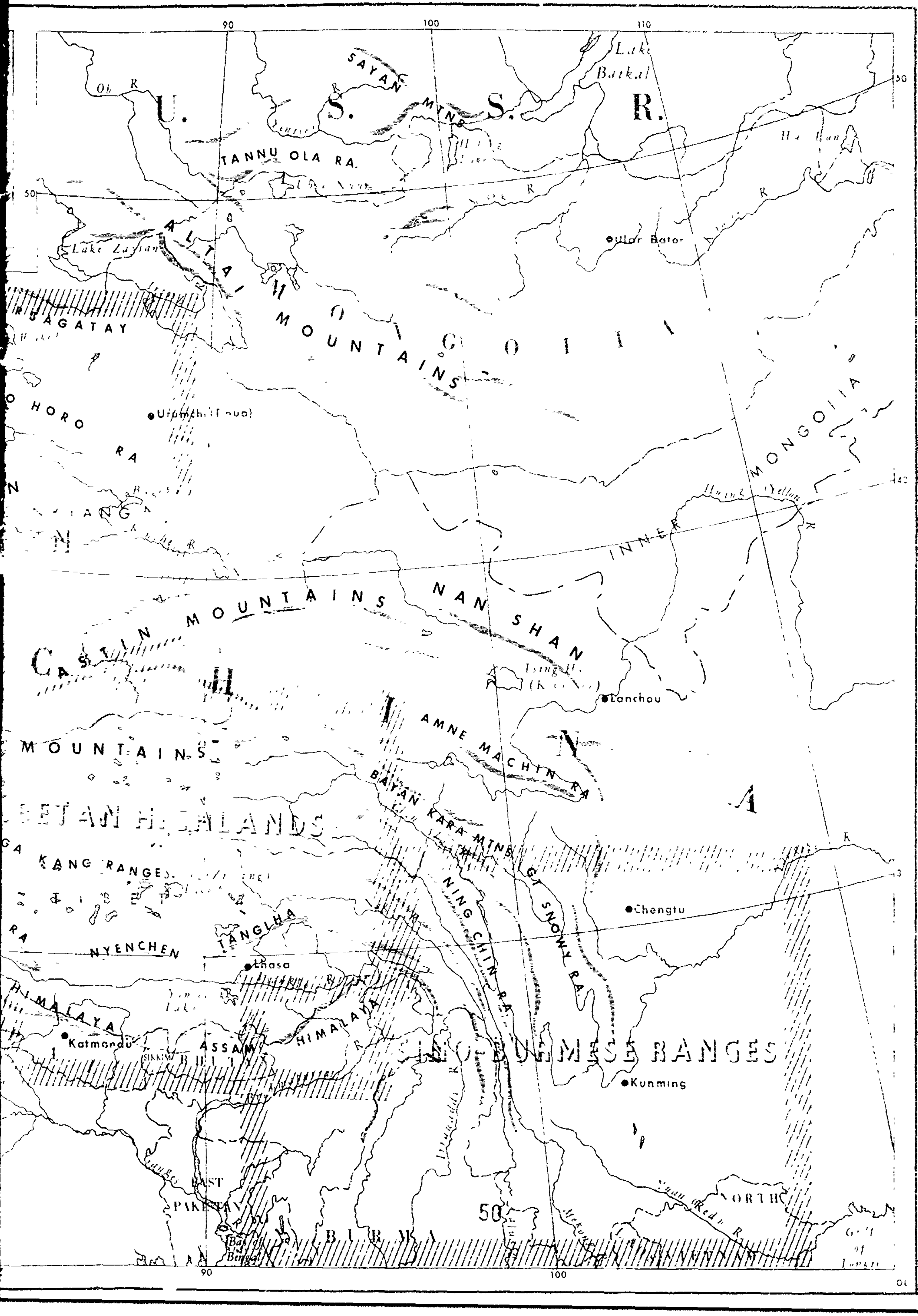
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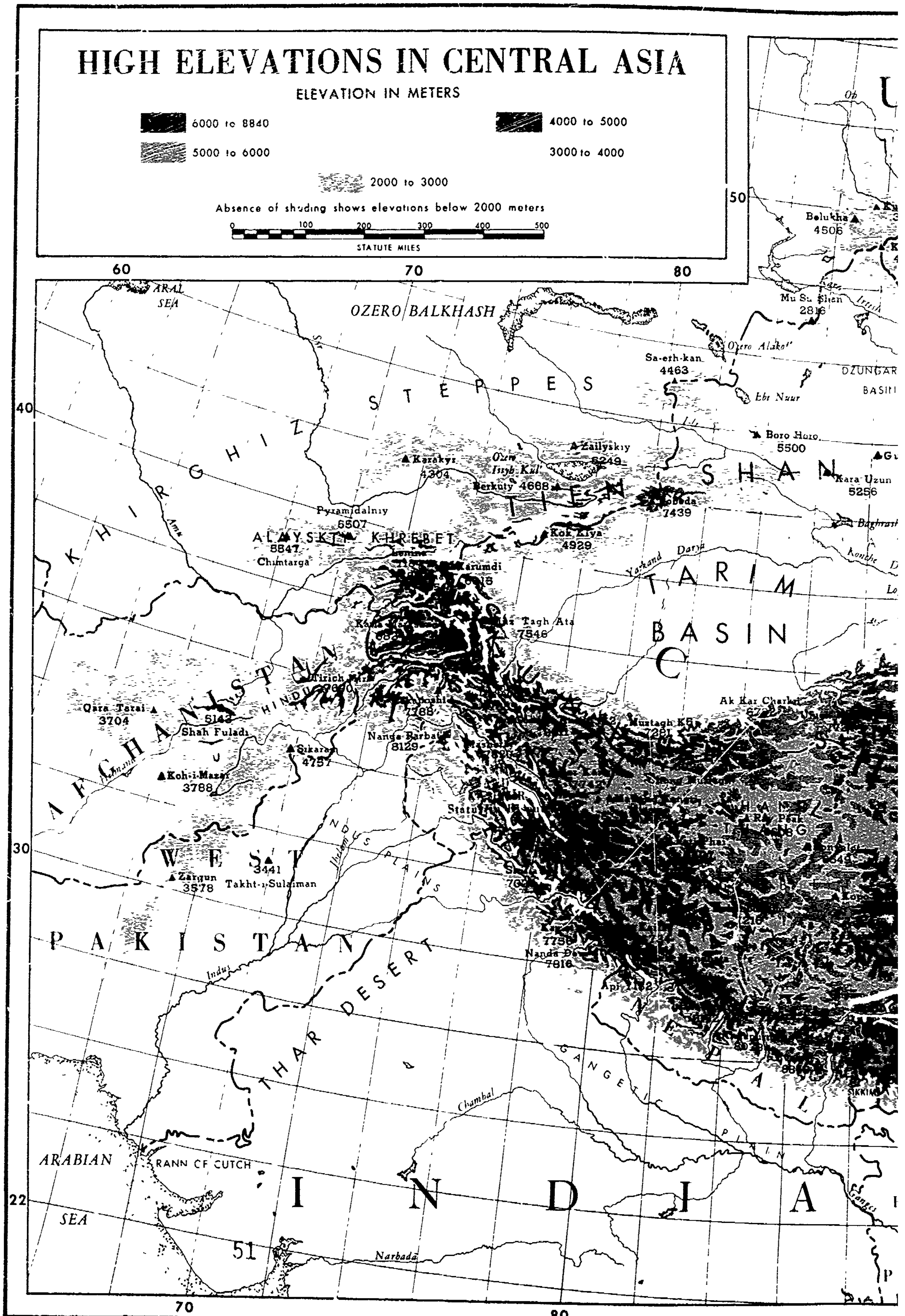
HIGH ELEVATIONS IN CENTRAL ASIA
ELEVATION IN METERS
6000 to 8840
4000 to 5000
5000 to 6000
3000 to 4000
2000 to 3000
Absence of shading shows elevations below 2000 meters
0 100 200 300 400 500
STATUTE MILES
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ARAL SEA
OZERO BALKHASH
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Ozero Alakol'
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Belukha 4506
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Zailyskiy 5249
Karakys 4304
Ozero Issyk Kul
Berkuty 4668
TIEN SHAN
Kara Uzun 5256
Pobeda 7439
Pyramidalniy 6507
ALAYSKIY KHREBET
5547 Chimtarga
Kok Kiya 4929
Yarkand Darya
TARIM BASIN
Tagh Ata 7546
Tirich Mir 7690
HINDU KUSH
Qara Tarai 3704
5143 Shah Fuladi
Sikaram 4757
Koh-i-Mazar 3788
Nanga Parbat 8129
Mustagh K2 8611
Ak Kar Charkhi
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WEST PAKISTAN
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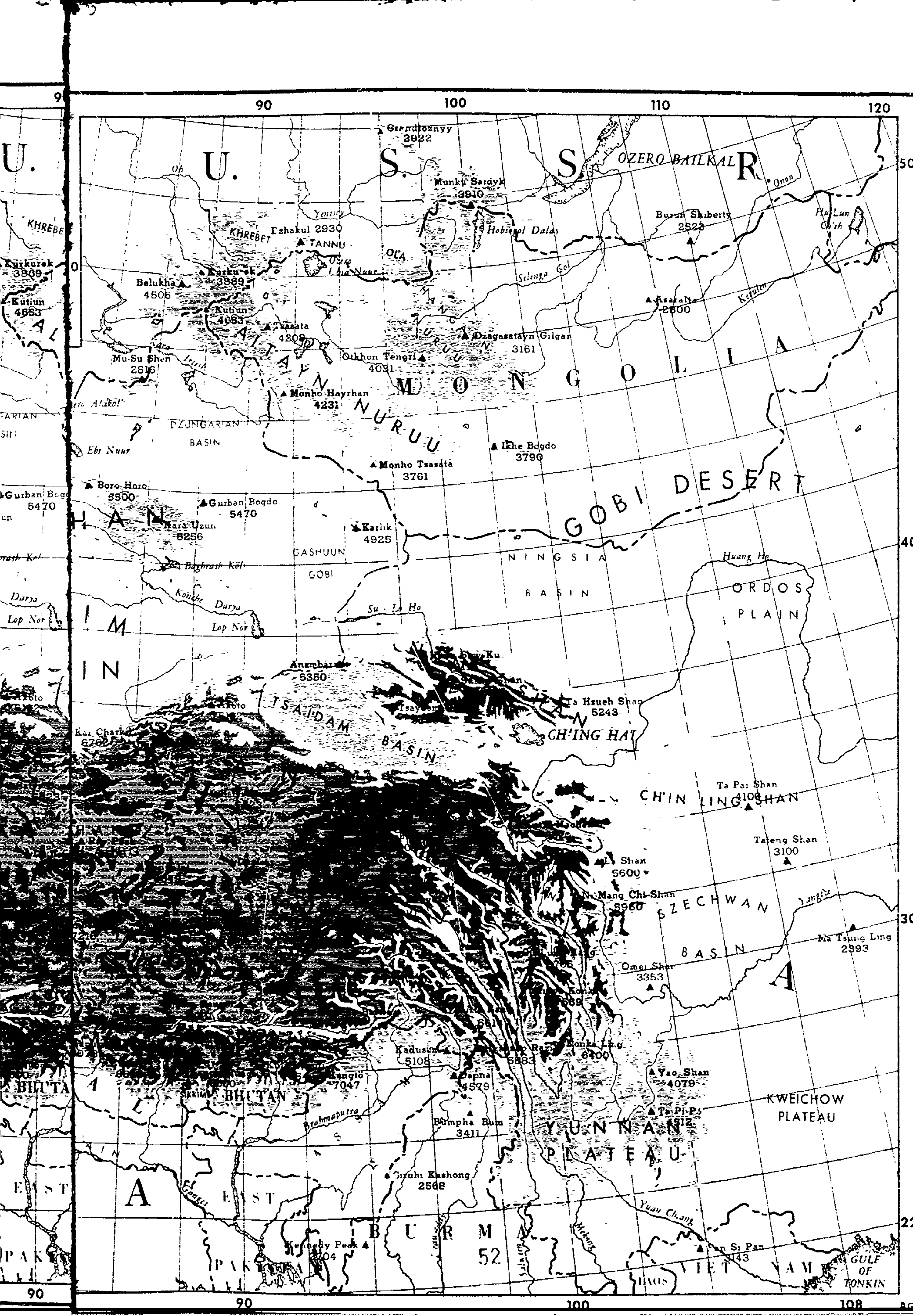

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Hobsogol Dalay
Selenga Gol
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Kurku-ok 3889
Kutiun 4663
Tsasata 4209
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Dzagasatayn Gilgar 3161
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Kara Uzun 6256
Karlik 4925
GASHUUN GOBI
NINGSIA BASIN
Huang Ho
ORDOS PLAIN
Baghrash Köl
Konche Darya
Lop Nor
Su-Lo Ho
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TSAIDAM BASIN
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Ta Pai Shan 4108
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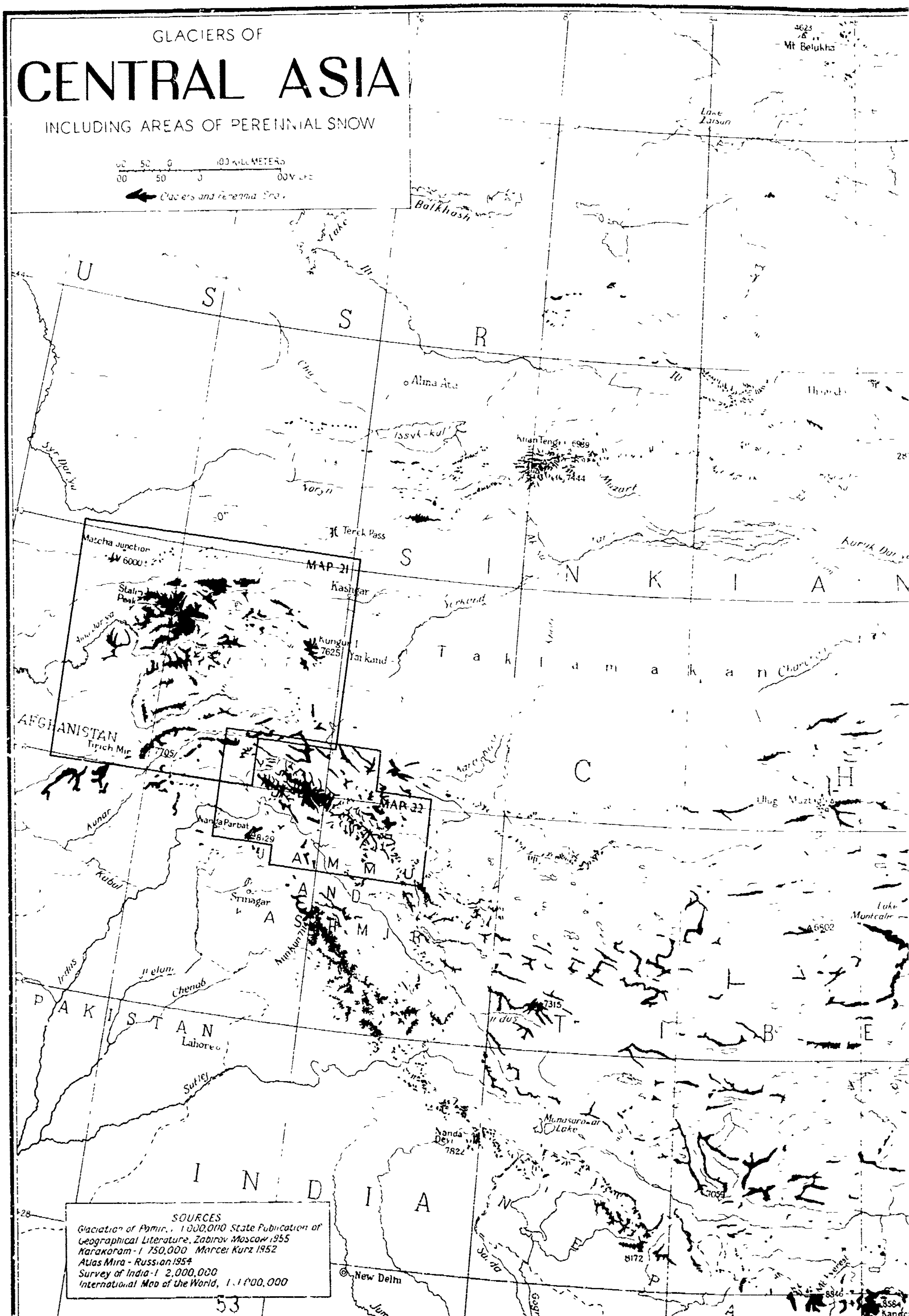
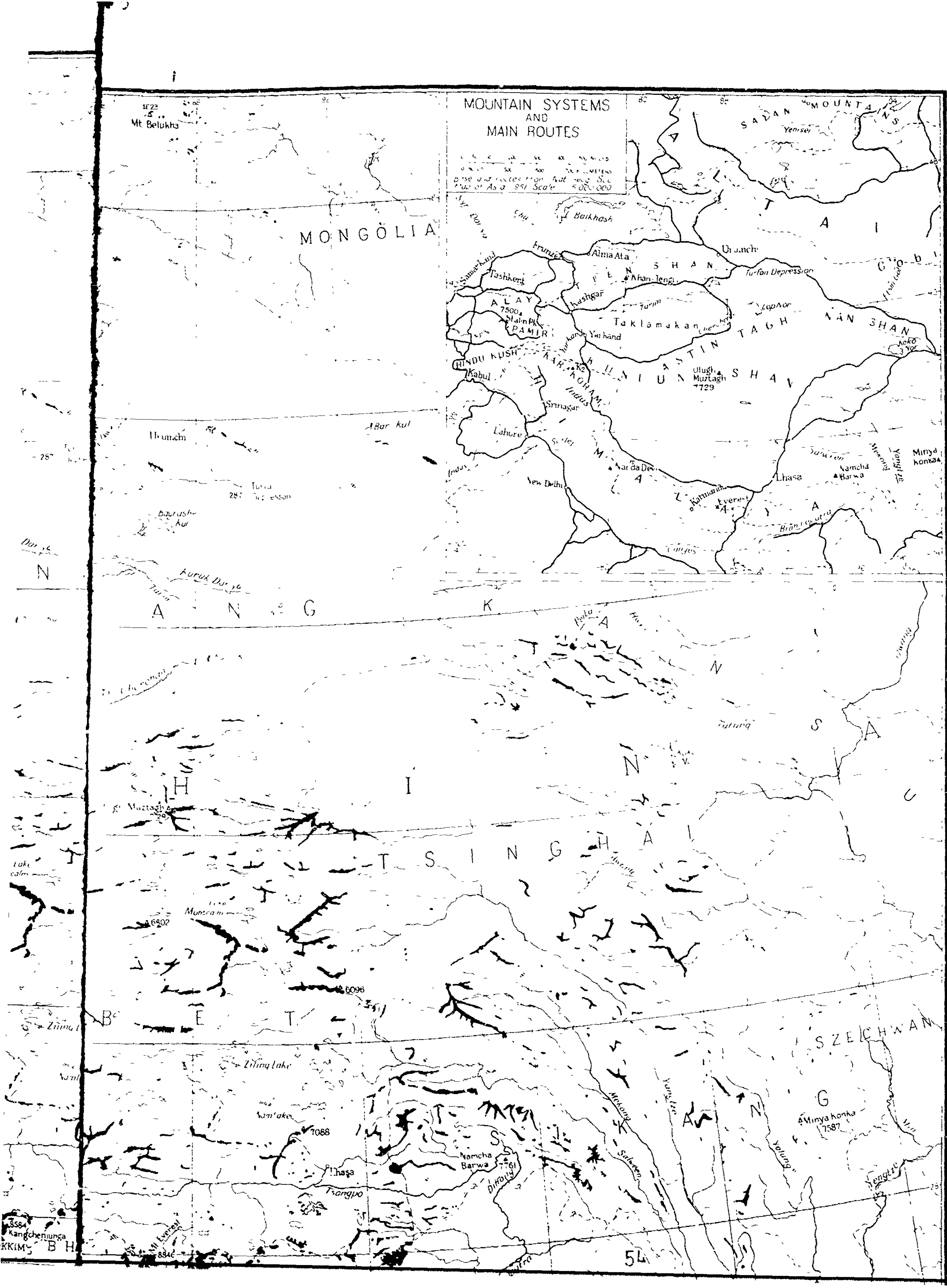
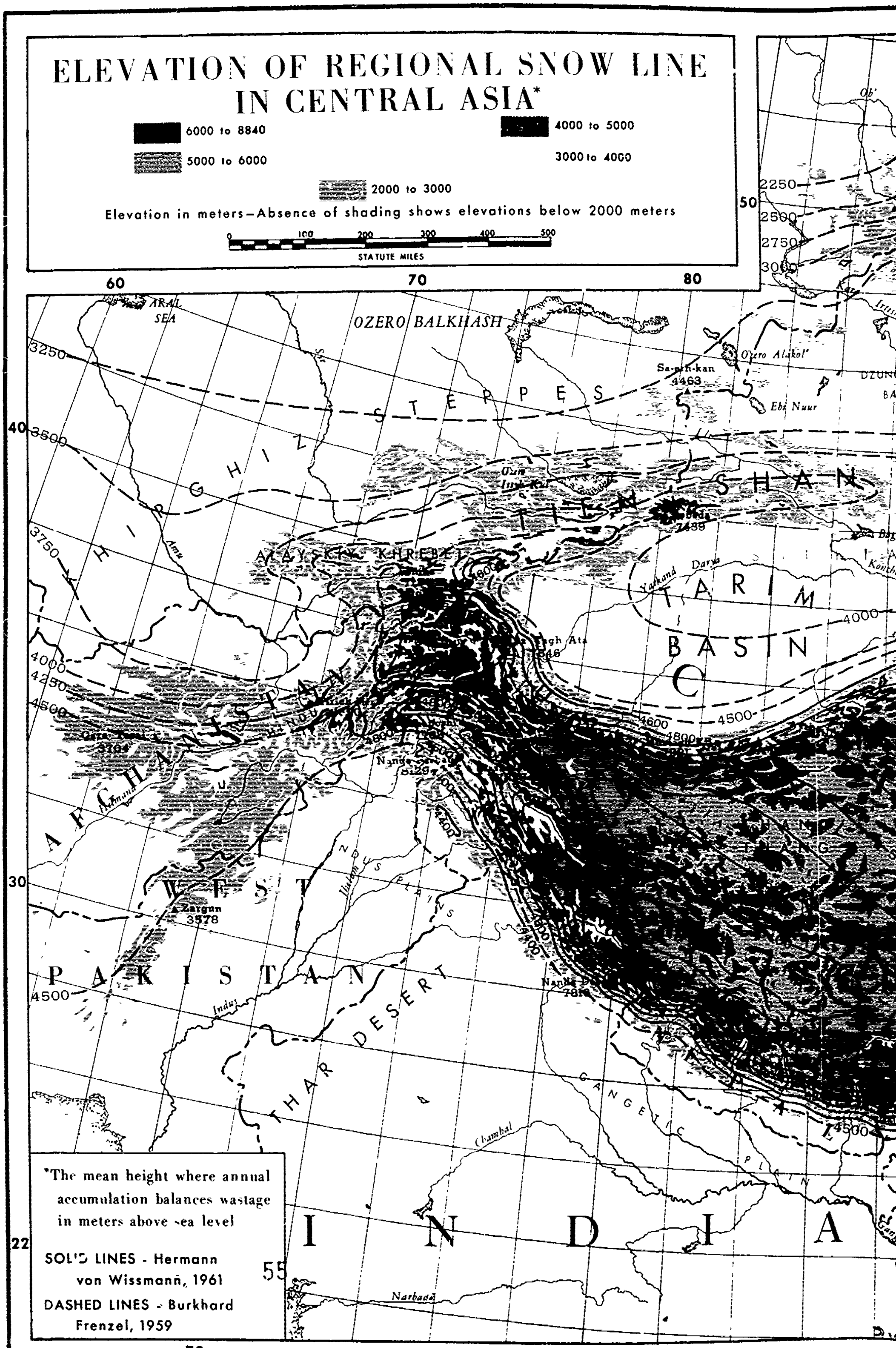
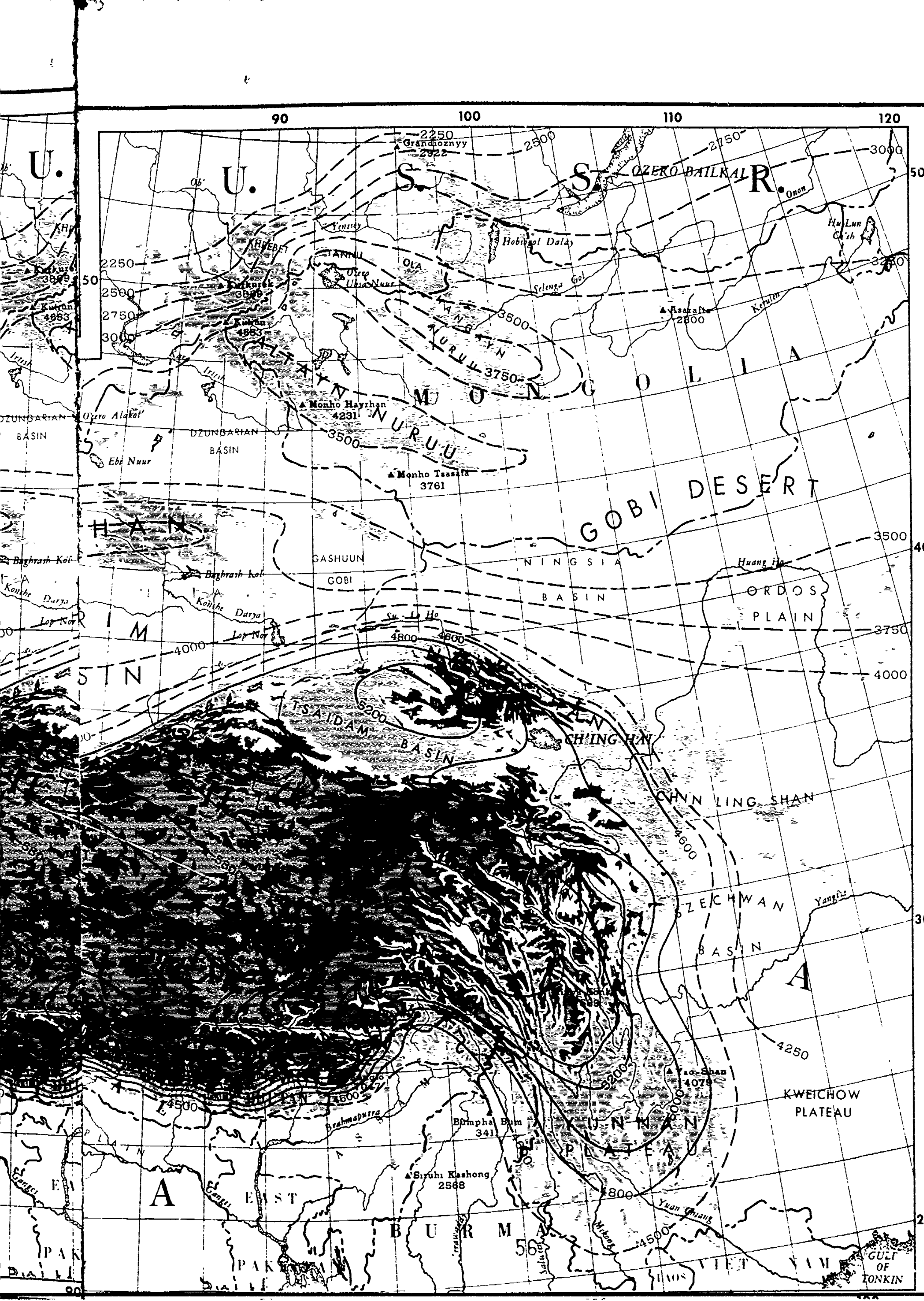
Kar Charki 6762
Tafeng Shan 3100
Li Shan 5600
Mang Chi Shan 5960
SZECHWAN BASIN
Yangtze
Ma Tsung Ling 2593
Omei Shan 3353
A
Kadusun 5108
Konka Ling 6400
Kangto 7047
Dapha 4579
Yao Shan 4079
BHUTAN
SIKKIM
Brahmaputra
Bumpha Bum 3411
Ta Pi Pa
KWEICHOW PLATEAU
YUNNAN PLATEAU
Saruhi Kashong 2568
Ganges
EAST
A
Yuan Chiang
Mekong
Salween
Kennedy Peak
BURMA
52
PAKISTAN
VIET NAM
LAOS
GULF OF TONKIN
108



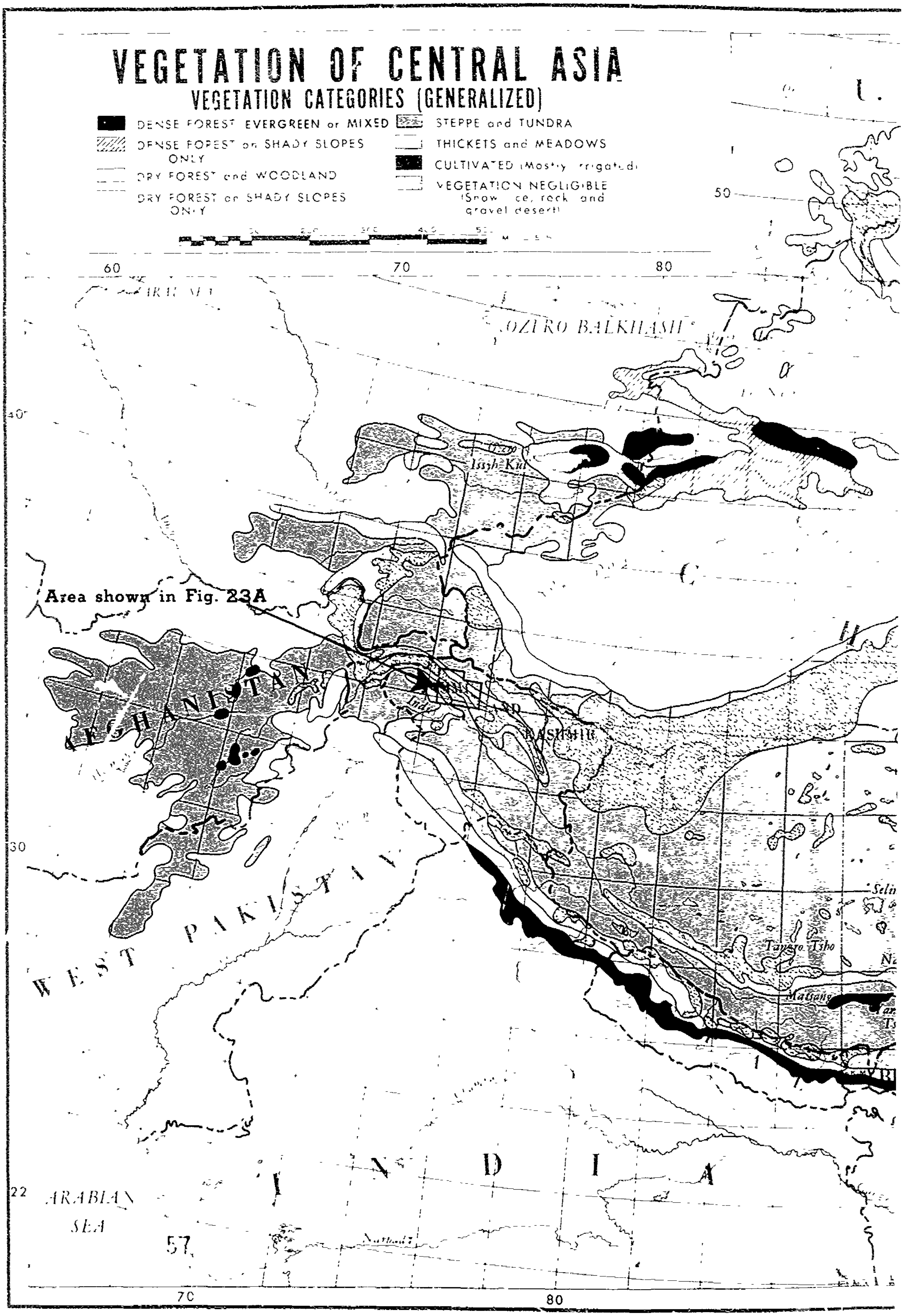
Map by American Geographical Society under U.S. Army Contract


MOUNTAIN SYSTEMS
AND
MAIN ROUTES
Mt Belukha
MONGOLIA
Balkhash
Alma Ata
Frunze
Tashkent
Samarkand
Urumchi
Turfan Depression
T'IEN SHAN
Khan-Tengri
Kashgar
Tarim
Lop Nor
ALAY
7500
Stalin Pk
PAMIR
Yarkand
Taklamakan
ASTIN TAGH
NAN SHAN
Koko Nor
HINDU KUSH
KARAKORAM
K2
KUNLUN SHAN
Ulugh Muztagh
7729
Kabul
Indus
Srinagar
Lahore
Sutlej
HIMALAYA
Nanda Devi
New Delhi
Katmandu
Everest
Lhasa
Namcha Barwa
Minya Konka
Salween
Mekong
Yangtze
Ganges
Brahmaputra
Bar Kul
Kuruk Darya
Tarim
SINKIANG
TSINGHAI
TIBET
SZECHWAN
Muztagh
Montcalm
6602
6096
Ziling Lake
Nam Tso
7088
Lhasa
Tsangpo
Namcha Barwa
7761
Dihang
Salween
Mekong
Yangtze
Yalung
Minya Konka
7587
Kangchenjunga
8846
Mt Everest
SIKKIM
BH


ELEVATION OF REGIONAL SNOW LINE IN CENTRAL ASIA*
6000 to 8840
4000 to 5000
5000 to 6000
3000 to 4000
2000 to 3000
Elevation in meters—Absence of shading shows elevations below 2000 meters
0 100 200 300 400 500
STATUTE MILES
60
70
80
50
40
30
22
ARAL SEA
OZERO BALKHASH
S T E P P E S
K I R G H I Z
T I E N S H A N
ALAYSKIY KHREBET
TARIM BASIN
AFGHANISTAN
HINDU KUSH
WEST PAKISTAN
PAKISTAN
THAR DESERT
INDUS PLAINS
GANGETIC PLAIN
INDIA
Sa-erh-kan 4463
Ozero Alakol'
Ebi Nuur
DZUNGA
Zargun 3578
Nanga Parbat 8126
Nanda Devi 7816
Muztagh Ata
Indus
Amu
Yarkand Darya
Chambal
Narbada
Ganges
Irtysh
Ob'
3250
3500
3750
4000
4250
4500
4600
4800
2250
2500
2750
3000
*The mean height where annual accumulation balances wastage in meters above sea level
SOLID LINES - Hermann von Wissmann, 1961
DASHED LINES - Burkhard Frenzel, 1959

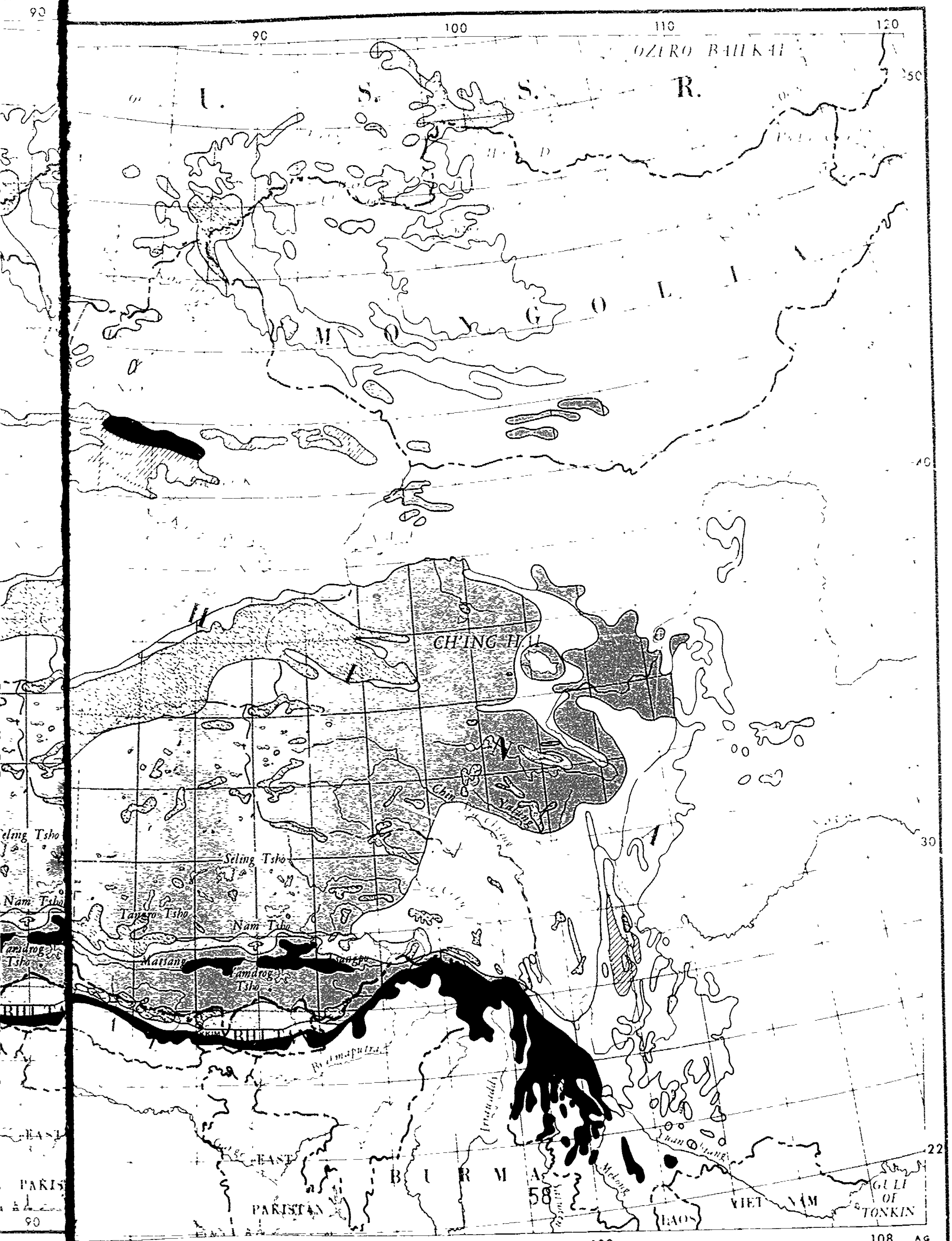


90
100
110
120
U.
U.
S.
S.
R.
OZERO BAIKAL
Onon
Hu Lun Ch'ih
Yenisey
Hobin Gol Dalay
TANNU OLA
Ozero Uvs Nuur
Selenga Gol
KHREBET
Kerulen
Asaraltu 2800
Grandioznyy 2922
KHANGAYN NURUU
ALTAYN NURUU
Monho Hayrhan 4231
Monho Tsasts 3761
MONGOLIA
GOBI DESERT
DZUNGARIAN BASIN
Ozero Alakol'
Ebi Nuur
Irtish
Ob'
GASHUUN GOBI
NINGSIA BASIN
ORDOS PLAIN
Huang Ho
Baghrash Kol
Konche Darya
Lop Nor
Su-Lo Ho
TSAIDAM BASIN
CH'ING HAI
CH'IN LING SHAN
SZECHWAN BASIN
Yangtze
Yao Shan 4079
KWEICHOW PLATEAU
YUNNAN PLATEAU
Brahmaputra
Bumpha Bum 3411
Sıruhı Kashong 2568
BURMA
EAST PAKISTAN
Ganges
Salween
Mekong
Yuan Chiang
VIET NAM
LAOS
GULF OF TONKIN
56
2250
2500
2750
3000
3250
3500
3750
4000
4250
4500
4600
4800
5200
5600
50
40
30
22


VEGETATION OF CENTRAL ASIA
VEGETATION CATEGORIES (GENERALIZED)
DENSE FOREST EVERGREEN or MIXED
DENSE FOREST on SHADY SLOPES ONLY
DRY FOREST and WOODLAND
DRY FOREST on SHADY SLOPES ONLY
STEPPE and TUNDRA
THICKETS and MEADOWS
CULTIVATED (Mostly irrigated)
VEGETATION NEGLIGIBLE (Snow, ice, rock and gravel desert)
60
70
80
50
40
30
22
OZERO BALKHASH
Issyk Kul
Area shown in Fig. 23A
AFGHANISTAN
KASHMIR
WEST PAKISTAN
INDIA
ARABIAN SEA
Tangro Tsho

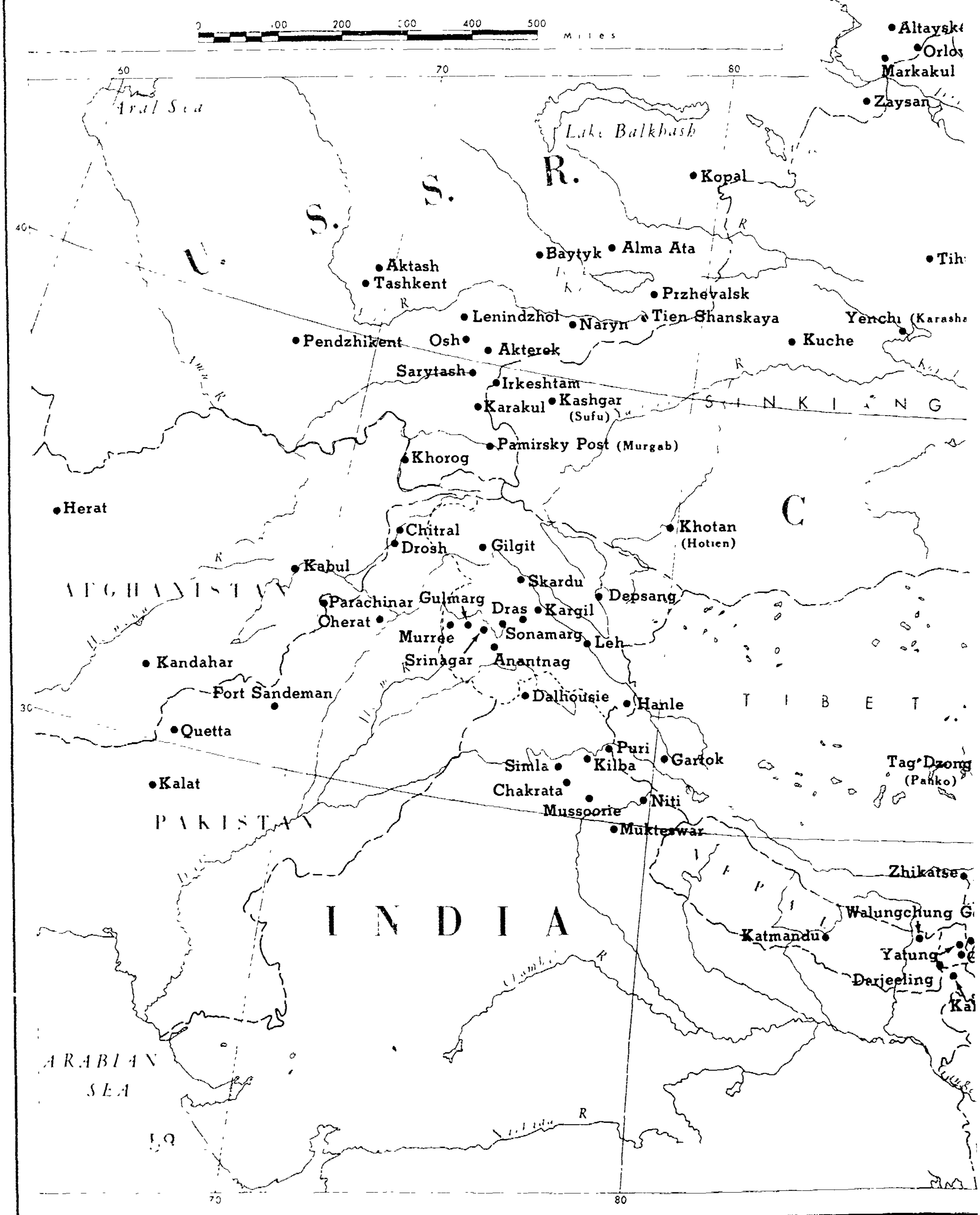
57

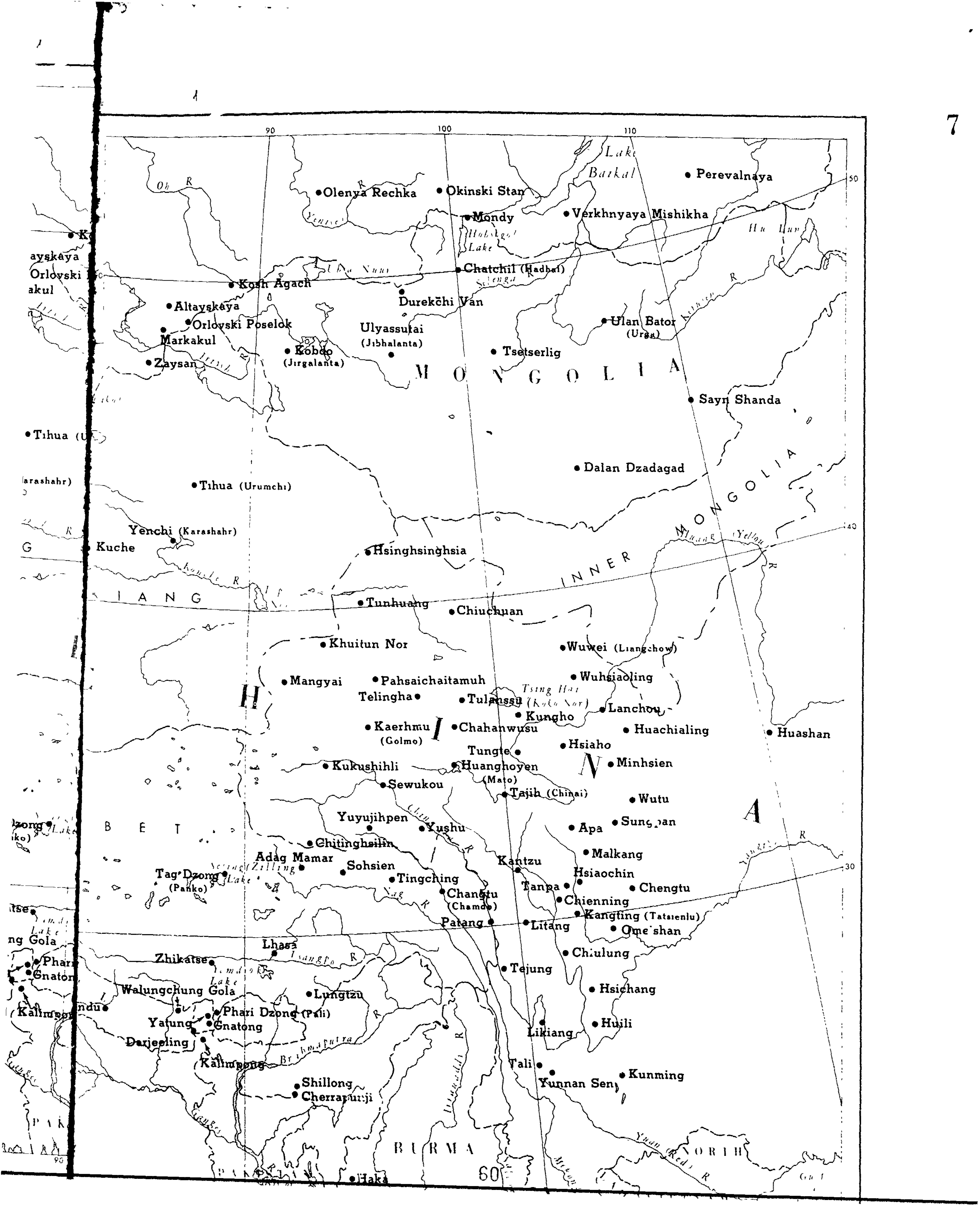
6

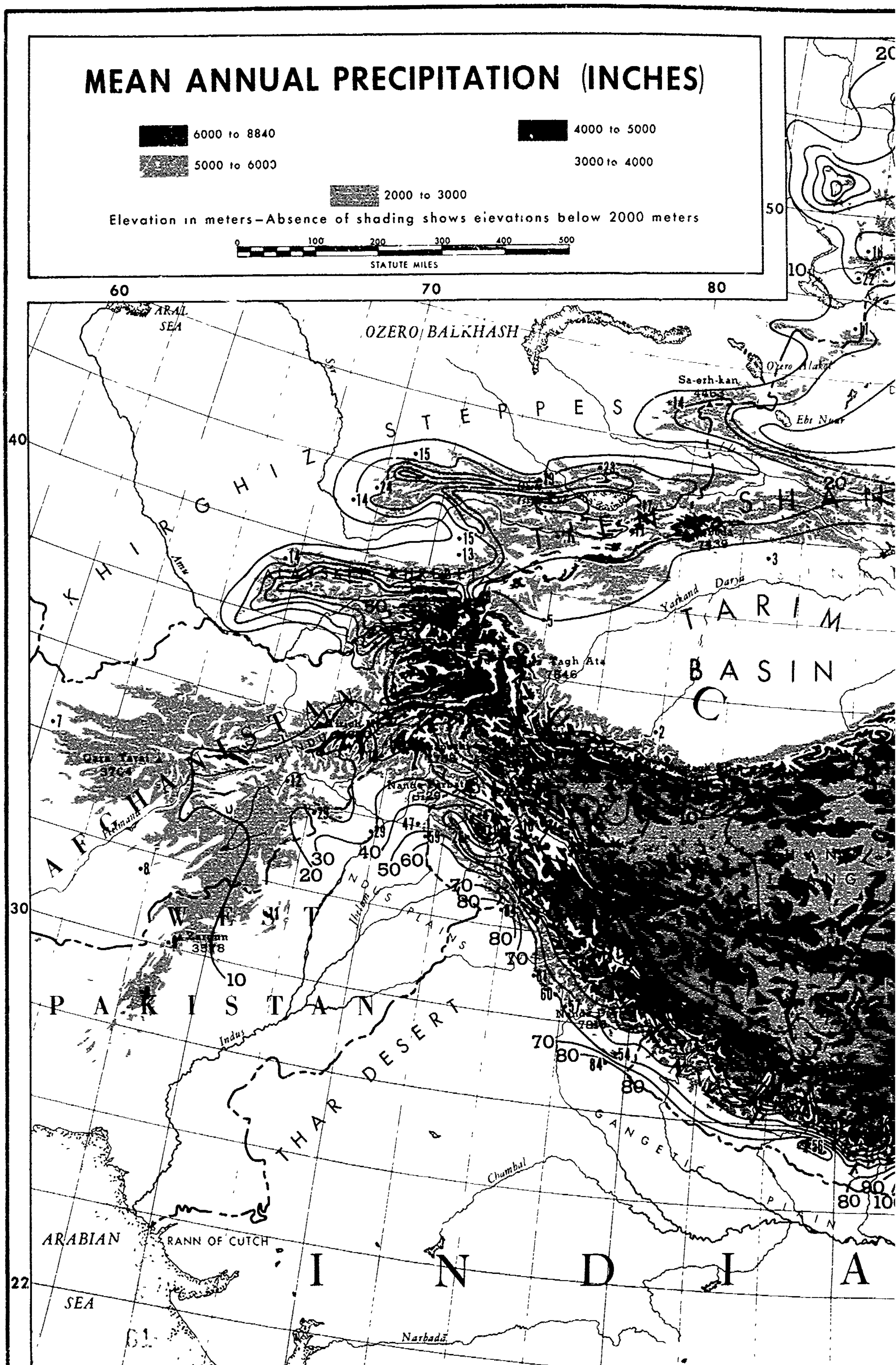


OZERO BAIKAL
U. S. S. R.
M O N G O L I A
CH'ING HAI
Seling Tsho
Nam Tsho
Tangro Tsho
Yamdrog Tsho
Matsang
Tsangpo
Brahmaputra
Irrawaddy
Salween
Mekong
B U R M A
PAKISTAN
EAST
VIET NAM
LAOS
GULF OF TONKIN
58
90
100
110
120
50
40
30
22
108

LOCATION OF CLIMATIC STATIONS IN CENTRAL ASIAN HIGHLANDS

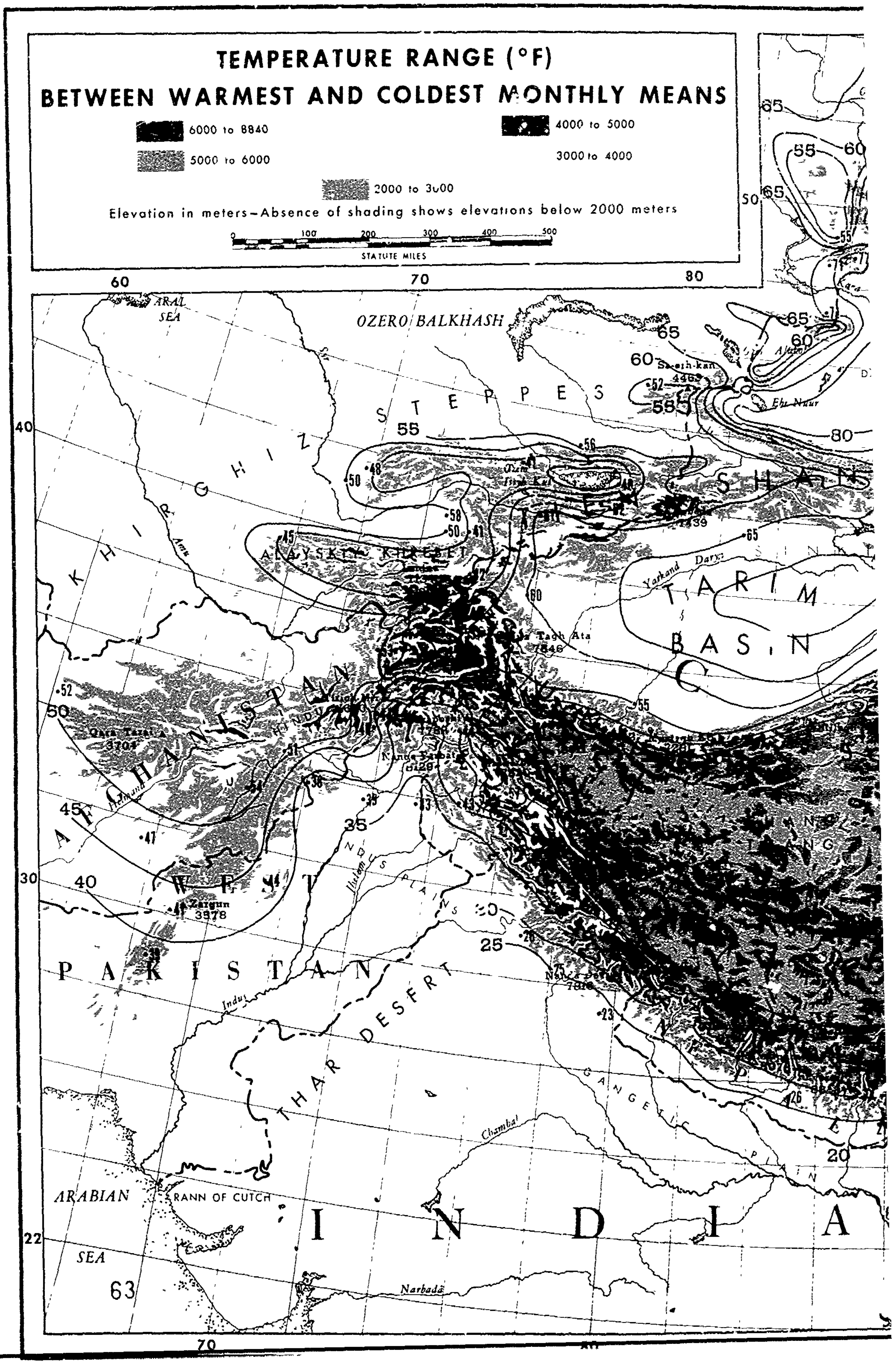



90
100
110
50
40
30
Lake Baikal
Perevalnaya
Olenya Rechka
Okinski Stan
Mondy
Verkhnyaya Mishikha
Kosogol Lake
Chatchil (Hadhal)
Kosh Agach
Durekchi Van
Altayskaya
Orlovski Poselok
Markakul
Zaysan
Kobdo (Jirgalanta)
Ulyassutai (Jibhalanta)
Tsetserlig
Ulan Bator (Urga)
MONGOLIA
Sayn Shanda
Tihua (Urumchi)
Dalan Dzadagad
INNER MONGOLIA
Yenchi (Karashahr)
Kuche
Hsinghsinghsia
Tunhuang
Chiuchuan
Khuitun Nor
Wuwei (Liangchow)
Mangyai
Pahsaichaitamuh
Wuhsiaoling
Telingha
Tulansu
Tsing Hai (Koko Nor)
Lanchow
Kungho
Kaerhmu (Golmo)
Chahanwusu
Huachialing
Huashan
Hsiaho
Tungte
Kukushihli
Huanghoyen (Mato)
Minhsien
Sewukou
Tajih (Chinai)
Wutu
Yuyujihpen
Yushu
Apa
Sungpan
CHINA
Chitinghsilin
Malkang
Adag Mamar
Sohsien
Kantzu
Hsiaochin
Tag Dzong (Panko)
Tingching
Tanpa
Chengtu
Changtu (Chamdo)
Chienning
Kangting (Tatsienlu)
Patang
Litang
Ome'shan
Lhasa
Chiulung
Zhikatse
Tejung
Hsichang
Walungchung Gola
Lungtzu
Phari Dzong (Pali)
Yatung
Gnatong
Huili
Likiang
Darjeeling
Kalimpong
Brahmaputra
Tali
Kunming
Yunnan Sen
Shillong
Cherrapunji
BURMA
NORTH
Yuan (Red) R
Haka
60

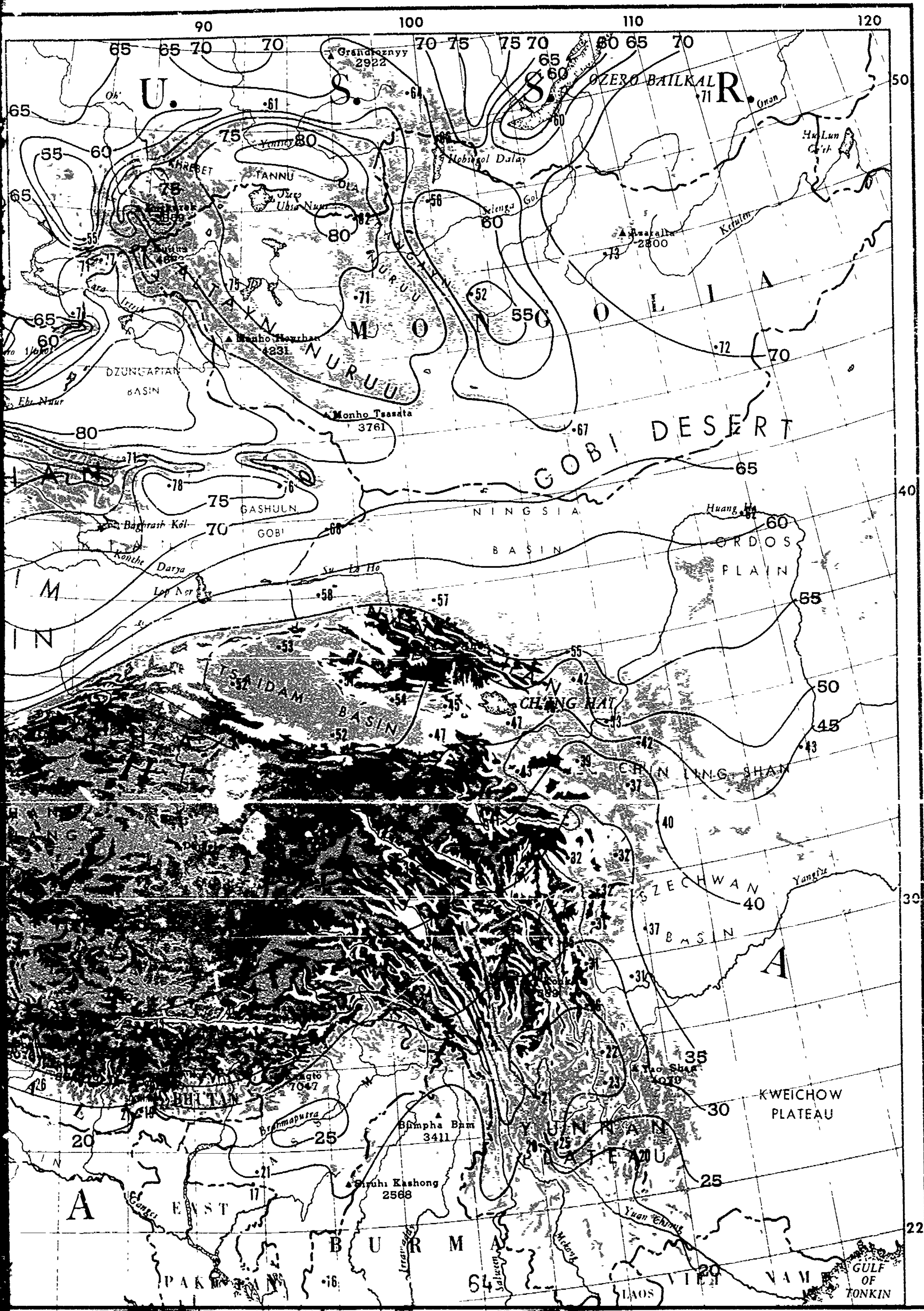


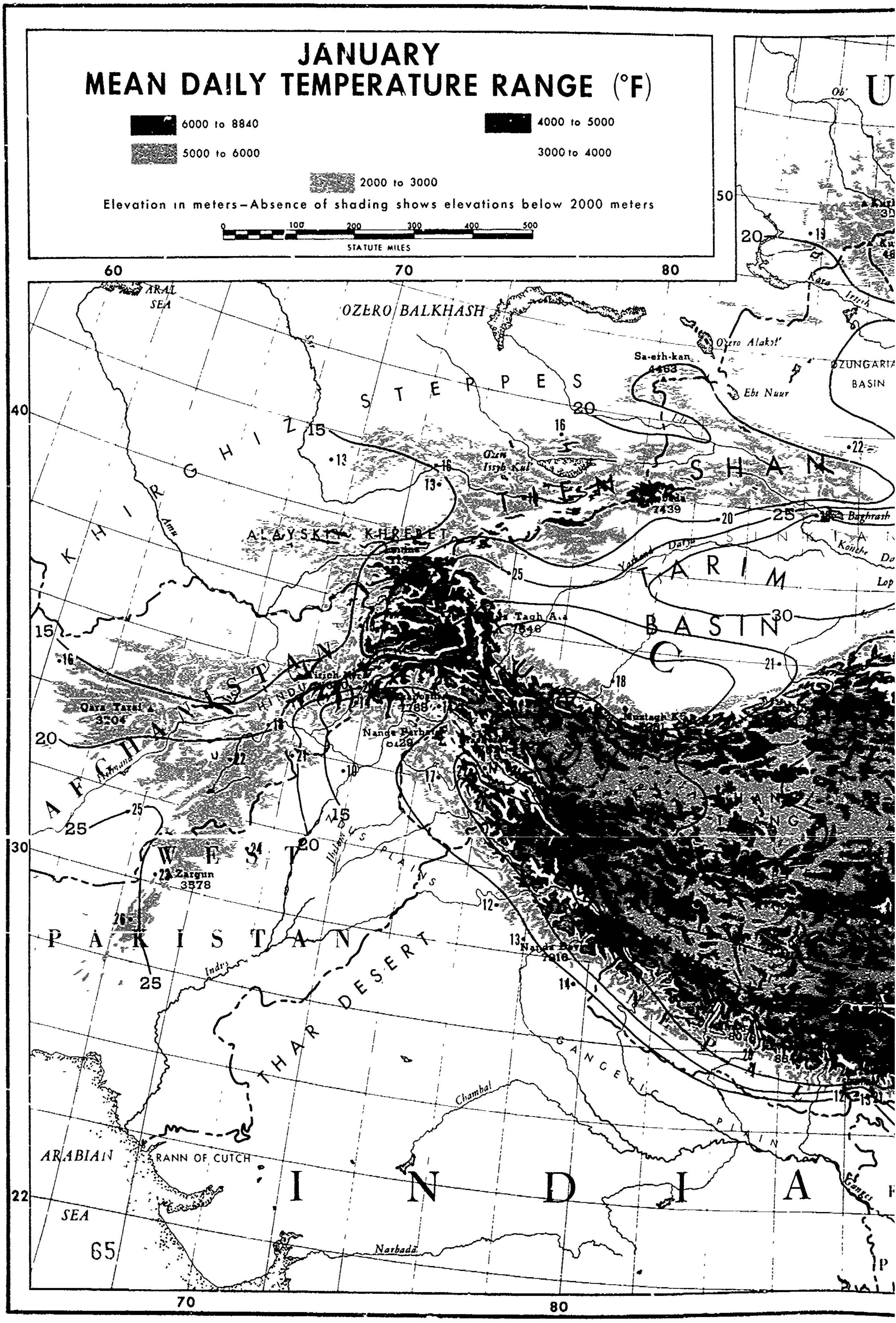
MEAN ANNUAL PRECIPITATION (INCHES)
6000 to 8840
4000 to 5000
5000 to 6000
3000 to 4000
2000 to 3000
Elevation in meters—Absence of shading shows elevations below 2000 meters
STATUTE MILES
ARAL SEA
OZERO BALKHASH
KHIRGHIZ STEPPES
TARIM BASIN
AFGHANISTAN
WEST PAKISTAN
THAR DESERT
INDUS PLAINS
GANGETIC PLAIN
ARABIAN SEA
RANN OF CUTCH
INDIA
Indus
Chambal
Narbada
Amu
Yarkand Darya
Sa-erh-kan
Tagh Ata

90
100
110
120
50
40
30
22
U. S. S. R.
OZERO BAIKAL
Onon
Hu Lun Ch'ih
Hobsgol Dalay
Selenga Gol
Kerulen
MONGOLIA
Monho Hayrhan 4231
Monho Tsasata 3761
DZUNGARIAN BASIN
Ebi Nuur
Irtysh
GOBI DESERT
GASHUUN GOBI
NINGSIA BASIN
Huang Ho
ORDOS PLAIN
Baghrash Köl
Konche Darya
Lop Nor
Su-Lo Ho
TSAIDAM BASIN
CH'ING HAI
CH'IN LING SHAN
SZECHWAN BASIN
Yangtze
KWEICHOW PLATEAU
Yuan Chiang
Mekong
Irrawaddy
Ganges
EAST PAKISTAN
VIET NAM
GULF OF

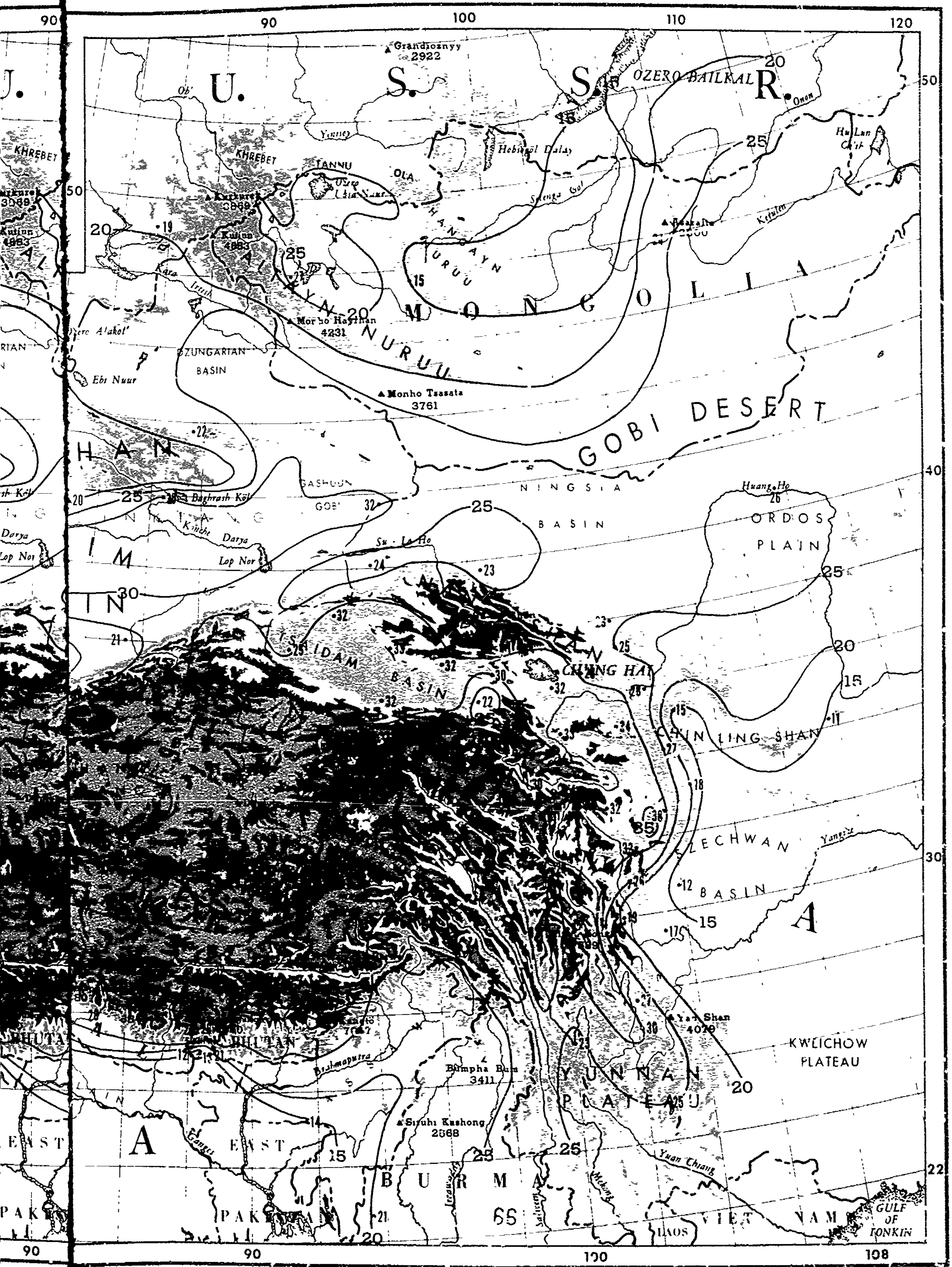


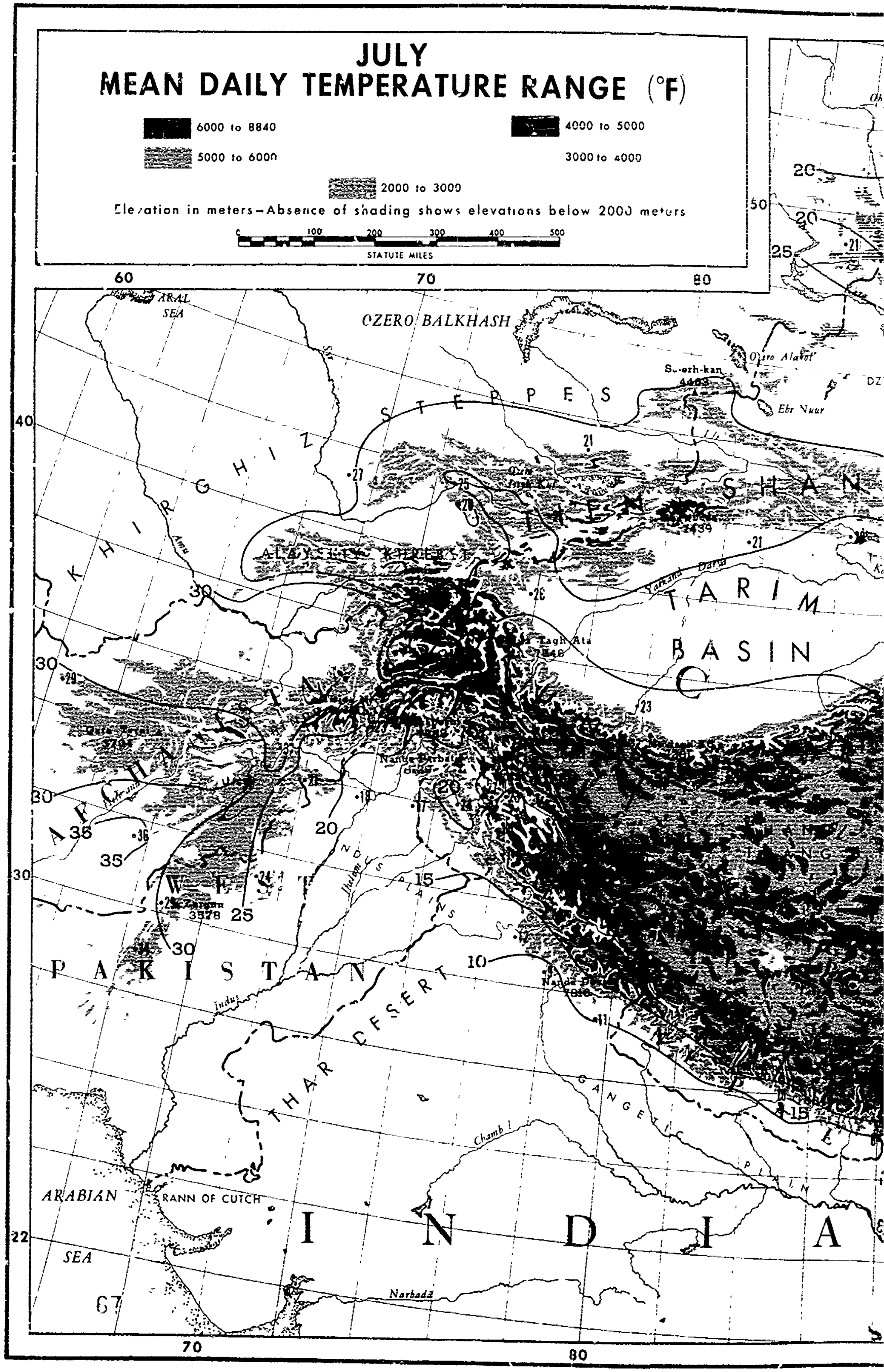
TEMPERATURE RANGE (°F)
BETWEEN WARMEST AND COLDEST MONTHLY MEANS
6000 to 8840
4000 to 5000
5000 to 6000
3000 to 4000
2000 to 3000
Elevation in meters—Absence of shading shows elevations below 2000 meters
STATUTE MILES
ARAL SEA
OZERO BALKHASH
STEPPES
KHIRGHIZ
ALAYSKIY KHREBET
TARIM BASIN
AFGHANISTAN
HINDU KUSH
WEST PAKISTAN
PAKISTAN
INDUS PLAINS
THAR DESERT
GANGETIC PLAIN
INDIA
ARABIAN SEA
RANN OF CUTCH
Amu
Indus
Jhelum
Chambal
Narbada
Helmand
Yarkand Darya
Zargun 3578
Nanga Parbat 8126
Tagh Ata 7546
Qara Tarat 3704
Ebi Nuur
Altai

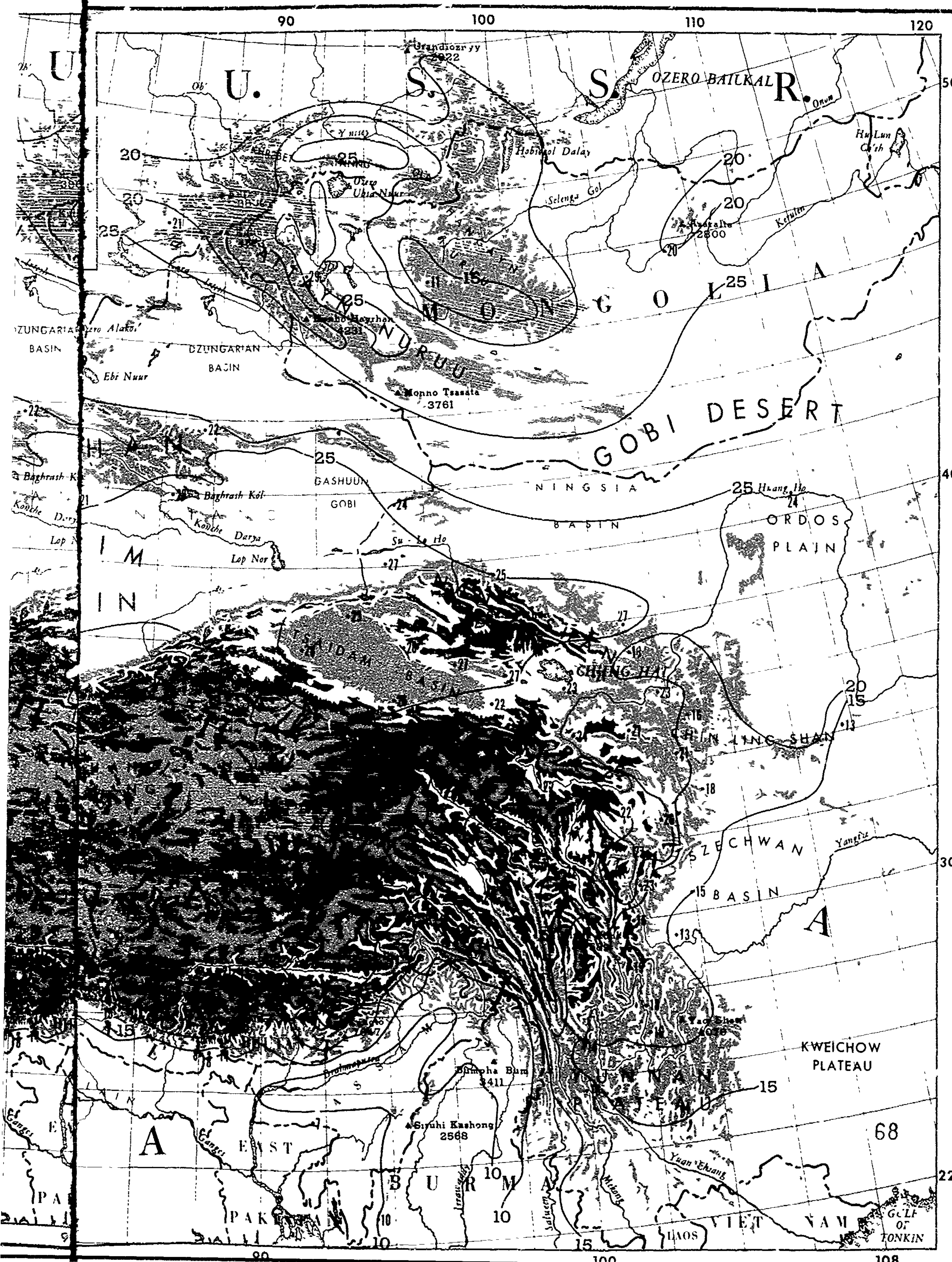

U. S. S. R.
OZERO BAILKAL
Grandioznyy 2922
Hobsogol Dalay
Selenga Gol
Onon
Kerulen
Hu Lun Ch'ih
TANNU OLA
KHREBET
Ubsa Nuur
ALTAYN NURUU
Monho Hayrhan 4231
DZUNGARIAN BASIN
Ebi Nuur
Monho Tsasata 3761
M O N G O L I A
GOBI DESERT
GASHUUN GOBI
Baghrash Köl
Konche Darya
Lop Nor
NINGSIA BASIN
Su Lo Ho
Huang Ho
ORDOS PLAIN
TSAIDAM BASIN
CHING HAI
CHIN LING SHAN
SZECHWAN BASIN
Yangtze
KWEICHOW PLATEAU
YUNNAN PLATEAU
Yao Shan
BHUTAN
Brahmaputra
Bumpha Bum 3411
Saramati 3826
Ganges
Irrawaddy
Salween
Mekong
Yuan Chiang
B U R M A
LAOS
VIET NAM
GULF OF TONKIN
PAKISTAN
90
100
110
120
50
40
30
22

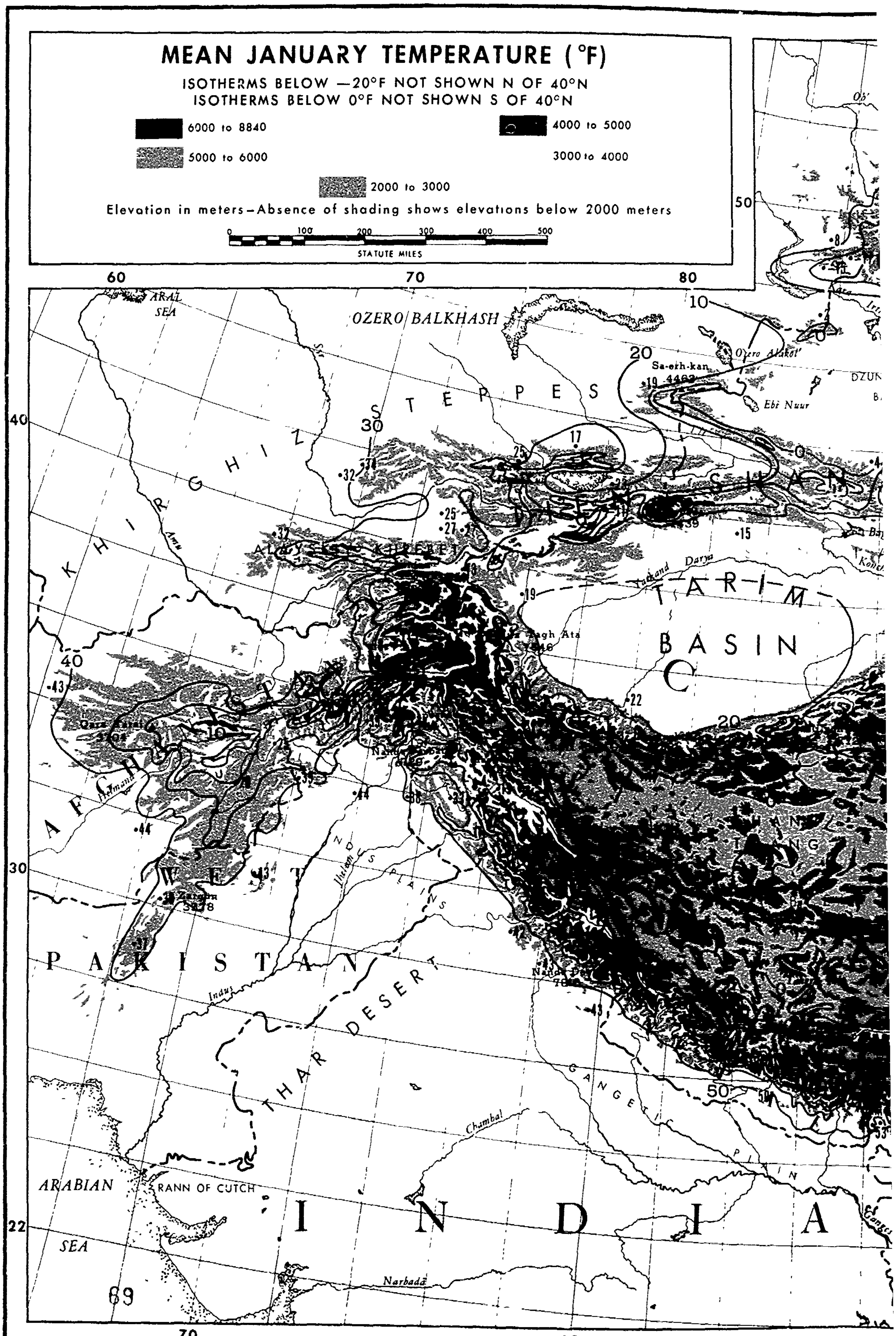


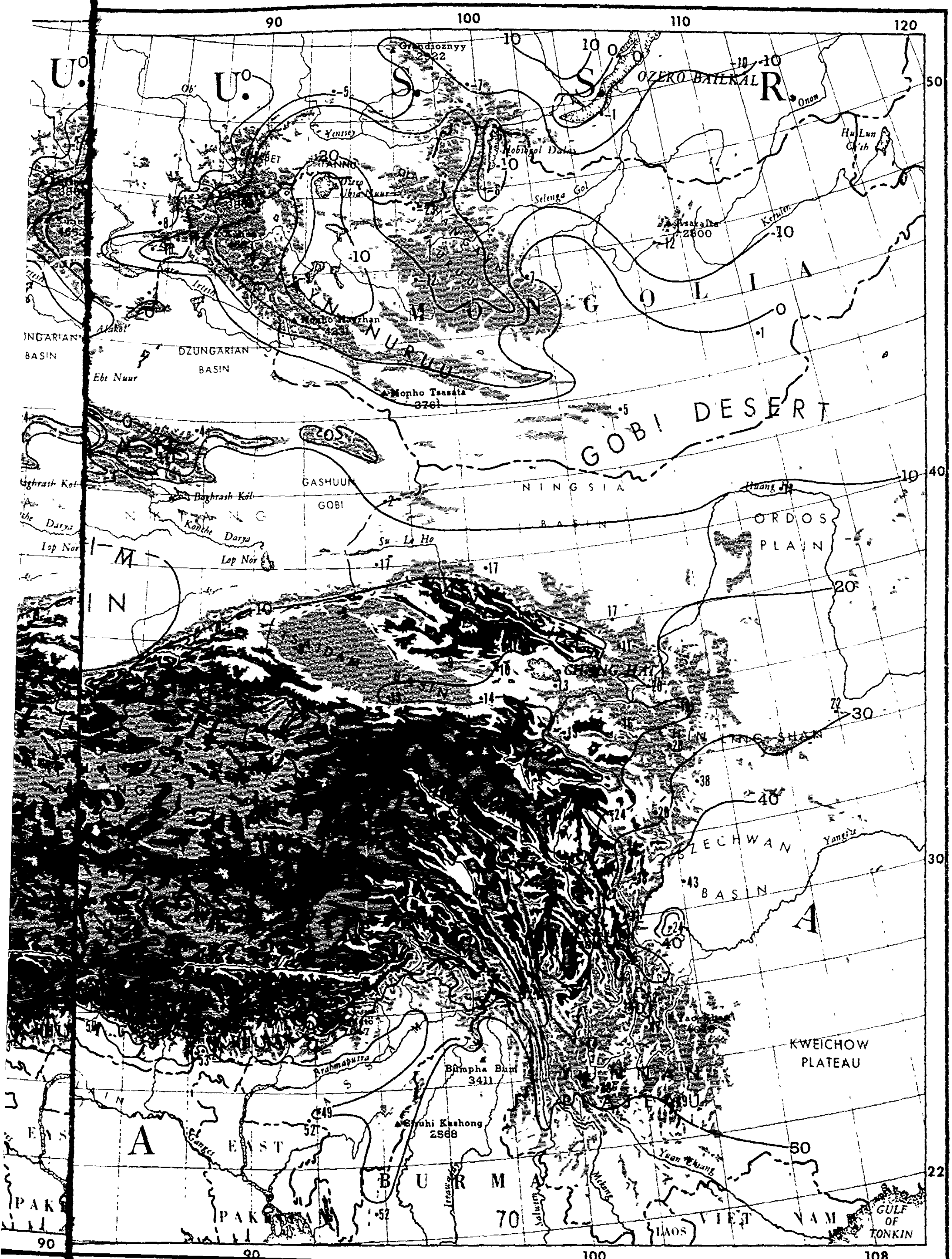
JANUARY
MEAN DAILY TEMPERATURE RANGE (°F)
6000 to 8840
4000 to 5000
5000 to 6000
3000 to 4000
2000 to 3000
Elevation in meters—Absence of shading shows elevations below 2000 meters
STATUTE MILES
ARAL SEA
OZERO BALKHASH
S T E P P E S
K H I R G H I Z
ALAYSKIY KHREBET
T I E N
S H A N
TARIM
BASIN
AFGHANISTAN
HINDU KUSH
WEST
PAKISTAN
THAR DESERT
INDUS PLAINS
GANGETIC PLAIN
ARABIAN SEA
RANN OF CUTCH
I N D I A
DZUNGARIA BASIN
Ebi Nuur
Sa-erh-kan
Zargun
3578
Nanga Parbat
Indus
Amu
Chambal
Narbada
Yarkand Darya
Baghrash


U. S. S. R.
OZERO BAIKAL
MONGOLIA
GOBI DESERT
DZUNGARIAN BASIN
Ebi Nuur
Ozero Alakol'
Monho Hayrhan 4231
Monho Tsasata 3761
Grandioznyy 2922
TANNU OLA
KHREBET
HANGAYN NURUU
Selenga Gol
Kerulen
Onon
Hu Lun Ch'ih
NINGSIA BASIN
ORDOS PLAIN
Huang Ho
Su - Lo Ho
Lop Nor
Baghrash Köl
TSAIDAM BASIN
CHING HAI
CHIN LING SHAN
SZECHWAN BASIN
Yangtze
KWEICHOW PLATEAU
YUNNAN PLATEAU
Yao Shan 4020
Bumpha Bum 3411
Saruhi Kashong 2568
Brahmaputra
Ganges
BHUTAN
BURMA
PAKISTAN
VIET NAM
LAOS
GULF OF TONKIN
Yuan Chiang
Mekong
Salween
Irrawaddy
EAST
A
90
100
110
120
108
50
40
30
22
65


JULY
MEAN DAILY TEMPERATURE RANGE (°F)
6000 to 8840
4000 to 5000
5000 to 6000
3000 to 4000
2000 to 3000
Elevation in meters–Absence of shading shows elevations below 2000 meters
STATUTE MILES
ARAL SEA
OZERO BALKHASH
STEPPES
KHIRGHIZ
TIEN SHAN
TARIM BASIN
AFGHANISTAN
WEST
PAKISTAN
INDUS PLAINS
THAR DESERT
GANGETIC PLAIN
INDIA
ARABIAN SEA
RANN OF CUTCH
Amu
Indus
Jhelum
Chambal
Narbada
Yarkand Darya
Ebi Nuur

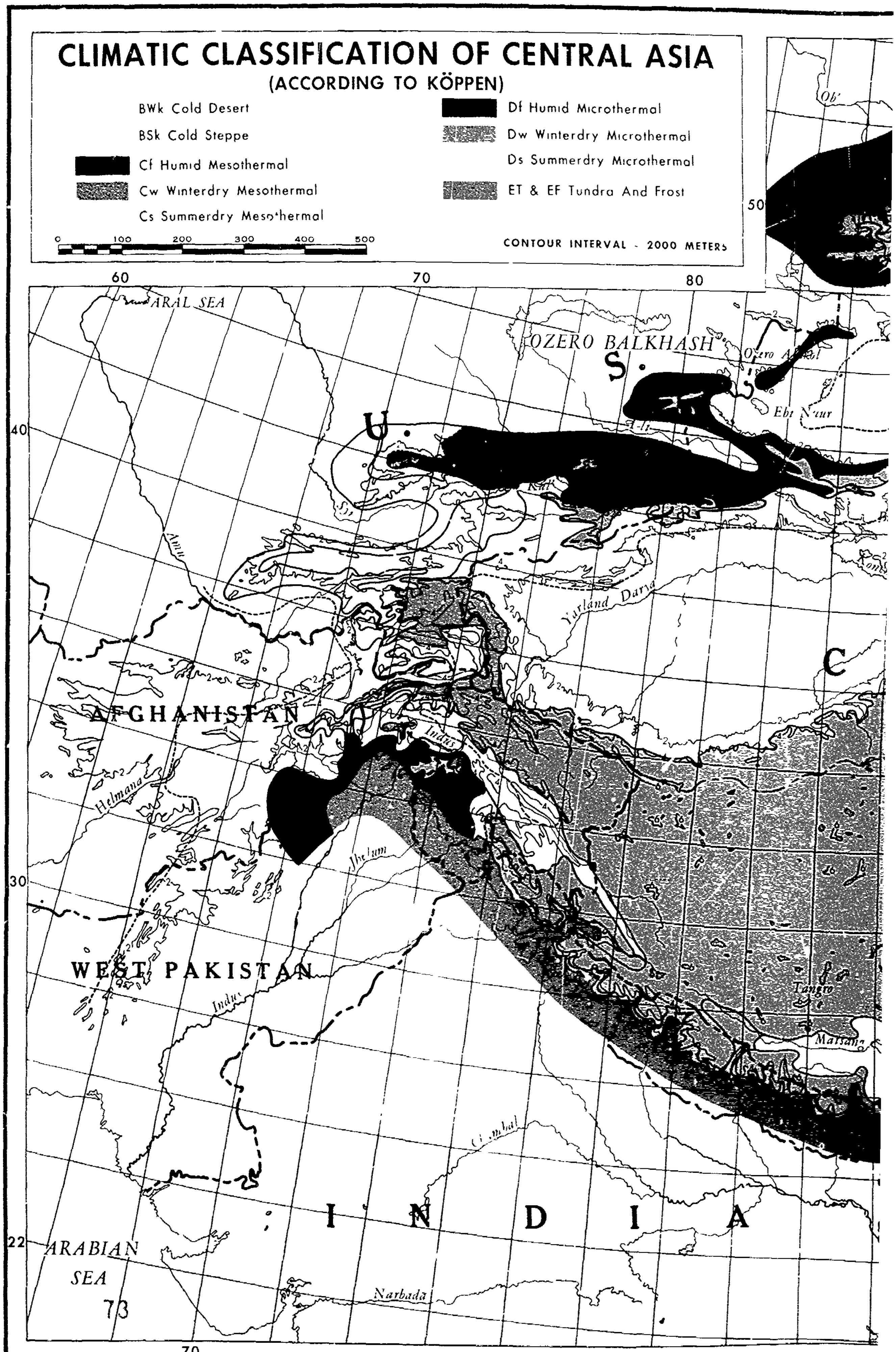

U. S. S. R.
OZERO BAIKAL
MONGOLIA
GOBI DESERT
DZUNGARIAN BASIN
GASHUUN GOBI
NINGSIA BASIN
ORDOS PLAIN
TSAIDAM BASIN
CHING HAI
TSIN LING SHAN
SZECHWAN BASIN
KWEICHOW PLATEAU
YUNNAN PLATEAU
BURMA
EAST PAKISTAN
VIET NAM
LAOS
GULF OF TONKIN
Monno Tsasata
3761
Hkakabo Razi
Bumpha Bum
3411
Saramati
Yao Shan
Lop Nor
Baghrash Köl
Ebi Nuur
Selenga Gol
Kerulen
Yangtze
Yuan Chiang
Mekong
Salween
Irrawaddy
Brahmaputra
Ganges
Huang Ho
Su Le Ho
Konche Darya
90
100
110
120
50
40
30
22
108


MEAN JANUARY TEMPERATURE (°F)
ISOTHERMS BELOW −20°F NOT SHOWN N OF 40°N
ISOTHERMS BELOW 0°F NOT SHOWN S OF 40°N
6000 to 8840
4000 to 5000
5000 to 6000
3000 to 4000
2000 to 3000
Elevation in meters–Absence of shading shows elevations below 2000 meters
STATUTE MILES
ARAL SEA
OZERO BALKHASH
KHIRGHIZ STEPPES
TARIM BASIN
AFGHANISTAN
WEST PAKISTAN
THAR DESERT
INDUS PLAINS
GANGETIC PLAIN
ARABIAN SEA
RANN OF CUTCH
INDIA
Chambal
Narbada
Indus
Jhelum
Amu
Helmand
Ebi Nuur
Sa-erh-kan
Nanga Parbat
69

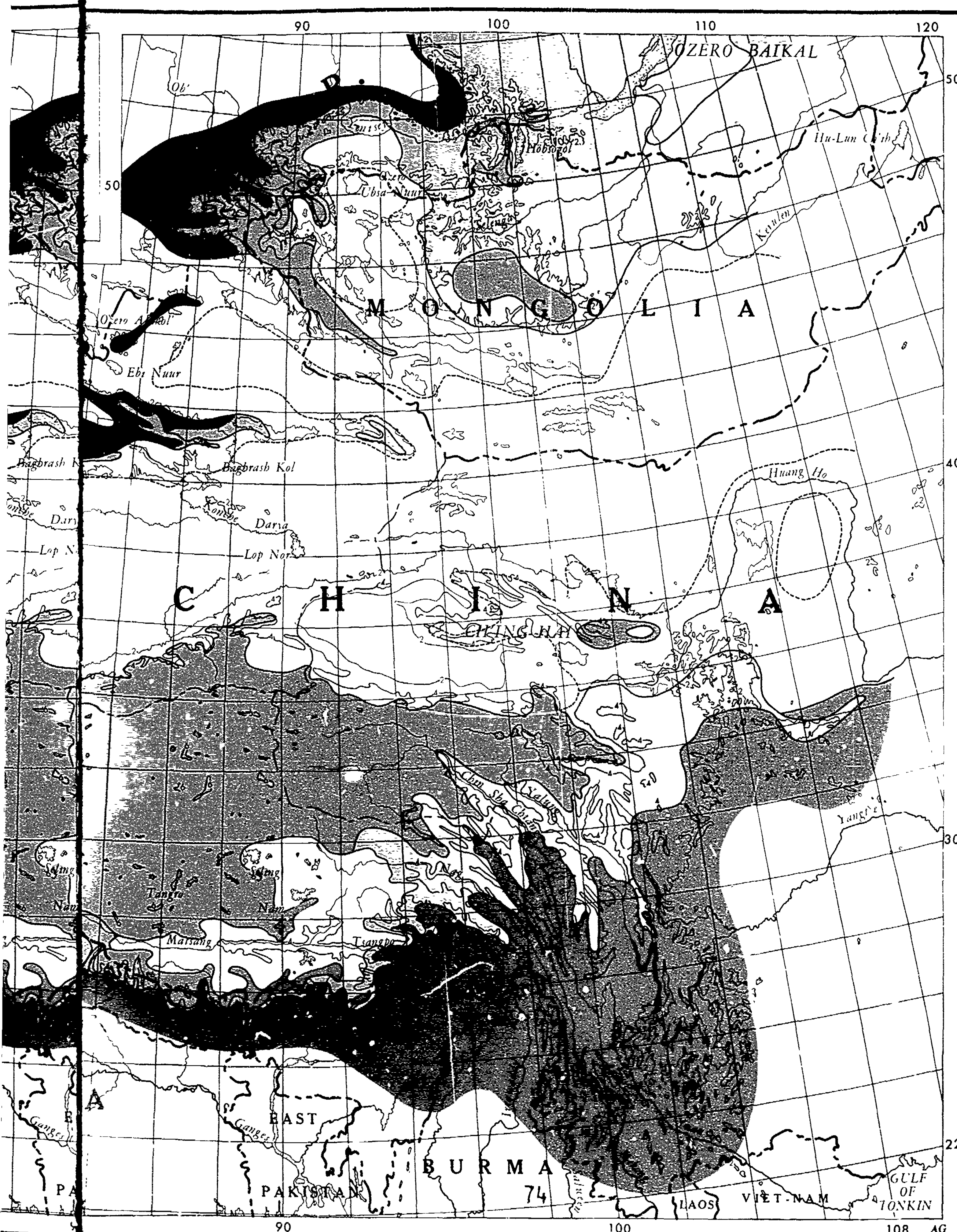

U.S.S.R.
OZERO BAIKAL
Grandioznyy 2922
Onon
Hu Lun Ch'ih
Yenisey
Selenga Gol
Kerulen
Asaraltu 2800
M O N G O L I A
Monho Hayrhan 4231
DZUNGARIAN BASIN
Ebi Nuur
Alakol'
Irtysh
Monho Tsasata 3761
GOBI DESERT
GASHUUN GOBI
NINGSIA BASIN
Huang Ho
ORDOS PLAIN
Baghrash Köl
Konche Darya
Lop Nor
Su-Le Ho
TSAIDAM BASIN
CHING HAI
SZECHWAN BASIN
Yangtze
KWEICHOW PLATEAU
Brahmaputra
Bumpha Bum 3411
Saramati
Shuhi Kashong 2568
EAST PAKISTAN
Ganges
BURMA
Irrawaddy
Salween
Mekong
Yuan Chiang
LAOS
VIET NAM
GULF OF TONKIN
90
100
110
120
50
40
30
22
108

MEAN JULY TEMPERATURE (°F)
ISOTHERMS BELOW +40°F NOT SHOWN
6000 to 8840
4000 to 5000
5000 to 6000
3000 to 4000
2000 to 3000
Elevation in meters–Absence of shading shows elevations below 2000 meters
STATUTE MILES
ARAL SEA
OZERO BALKHASH
KHIRGHIZ STEPPES
TARIM BASIN
PAKISTAN
THAR DESERT
INDIA
ARABIAN SEA
RANN OF CUTCH
Chambal
Narbada
Indus
Jhelum
Amu
Yarkand Darya
Ebi Nuur


U. S. S. R.
OZERO BAIKAL
MONGOLIA
GOBI DESERT
DZUNGARIAN BASIN
GASHUUN GOBI
NINGSIA BASIN
ORDOS PLAIN
TSAIDAM BASIN
CHING HAI
CHIN LING SHAN
SZECHWAN BASIN
KWEICHOW PLATEAU
YUNNAN PLATEAU
BURMA
PAKISTAN
VIET NAM
GULF OF
Grandiozny 2922
Monhe Hayrhan 4231
Monho Tsasata 3761
Asaralta 2800
Bumpha Bum 3411
Yao Shan 4076
Huang Ho
Yangtze
Brahmaputra
Ganges
Irrawaddy
Salween
Mekong
Yuan Chiang
Selenga Gol
Kerulen
Onon
Hu Lun Ch'ih
Ebi Nuur
Lop Nor
Su - Lo Ho
90
100
110
120
50
40
30
22



CLIMATIC CLASSIFICATION OF CENTRAL ASIA
(ACCORDING TO KÖPPEN)
BWk Cold Desert
BSk Cold Steppe
Cf Humid Mesothermal
Cw Winterdry Mesothermal
Cs Summerdry Mesothermal
Df Humid Microthermal
Dw Winterdry Microthermal
Ds Summerdry Microthermal
ET & EF Tundra And Frost
0 100 200 300 400 500
CONTOUR INTERVAL - 2000 METERS
60
70
80
50
40
30
22
ARAL SEA
OZERO BALKHASH
Eb Nuur
Amu
Yarkand Darya
AFGHANISTAN
Indus
Helmand
Jhelum
WEST PAKISTAN
Indus
Tangra
INDIA
ARABIAN SEA
Narbada
70
80


OZERO BAIKAL
Ob'
Hu-Lun Ch'ih
Hobsogol
Ubsa-Nuur
Kerulen
M O N G O L I A
Ozero Ayrbol'
Ebi Nuur
Bagbrash Kol
Huang Ho
Konche Darya
Lop Nor
C H I N A
CH'ING HAI
Chin Sha Chiang
Yalung
Yangt'e
Tangra
Nam
Matsang
Tsangpo
EAST
Ganges
B U R M A
PAKISTAN
LAOS
VIET-NAM
GULF OF TONKIN
90
100
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PART II

SECTIONAL SUMMARIES

1. THE SINO-BURMESE RANGES

a. Configuration

The Sino-Burmese Ranges, with the exception of their northern extensions, are shown on Maps 15 and 16. They comprise a series of parallel ranges generally trending north-south in the southern part of the study area but arcing inland toward the northwest. These ranges are separated by long gorges through which flow tributaries of the great rivers of Southeast Asia - the Yangtze, Mekong, Salween, and Irrawaddy. The most easterly of the high ranges is the Great Snowy Range (Ta Hsueh Shan), dominated by China's highest peak, Minya Konka (7,592 m) in western Szechwan* province. South of the Great Snowy Range, in Yunnan province, the highlands lose their north-south trend in the highly dissected Yunnan Plateau.

The northern portion of the Sino-Burmese Ranges merges into the Kun Lun Mountains and the Nan Shan, both trending more westerly but separated by the Tsing Hai and Tsaidam basins. The Kun Lun Mountains, forming the northern rim of the Tibetan Highlands, are discussed in the next section of this study. The Nan Shan lies mostly within China proper and is included in this section, although it is entirely outside the area shown on Maps 15 and 16.

The general crest elevation of the Nan Shan is about 4,000 m, while the basin floors range between 2,000 and 3,000 m. The high-level (3,000 m) intermontane valleys are 90 to 120 km long and 2 to 5 km wide with gently sloping sidewalls. They have alluvial sand and gravel floors, and contain a braided, sluggish drainage system interrupted by swamps. Much of the terrain is covered with wind-blown silts and is subject to dust storms.

* Some maps show western Szechwan and East Tibet as the province of Sikang, which was created in 1908. The present regime of mainland China, however, has restored the earlier Szechwan-Tibet boundary.

The broad, flanking slopes are dissected by dry washes. For the most part vehicular traffic can proceed rapidly, with only swamp areas posing hindrances in an otherwise favorable transport region. Although some movement across ranges may be possible through low divides, it would be confined to a small scale until roads were constructed.

The principal streams in the Sino-Burmese Ranges begin in high depressions on the Tibetan Plateau. At their sources these streams occupy relatively straight, broad valleys whose elevations range between 3,000 m and 4,000 m. The valleys are floored by alluvial sands and gravels with silt cappings and carry perennial, shallow, braided streams.

After leaving the high mountains at approximately 28° N, the streams flow through deep, narrow, closely parallel valleys which follow the structural trend of the arc. The Salween, Mekong and Yangtze Rivers flow through similar gorges, and at their closest point all three rivers are within 60 kilometers of one another. Tributary inflow is in the form of cascades over the valley sides. Passage through these canyons is difficult.

The Yunnan plateau is not rugged. Mountains rise gently from its surface and most are rounded. As they cross the plateau, the rivers diverge and the Yangtze turns easterly, while the Mekong and Salween flow southward, ultimately through Vietnam and Thailand, respectively.

The eastern approaches to the Sino-Burmese Ranges, chiefly from China, are through highly dissected, rounded hills. Valleys are narrow and deep, but are usually terraced. The high-level uplands surrounding and south of the Amne Machin Range are accessible through the large valley of the Yellow River (Huang Ho). Many sites on these uplands, as well as on the Yunnan Plateau, would be suitable for air-drop operations.

b. Water supply

The large rivers always contain ample water, even in the driest areas. Because of the narrowness of the major rivers in Yunnan, their level may fluctuate seasonally by 10 to 30 meters. Small streams on both the eastern and western sides contain water throughout the year. Farther north, on the plateau near Amne Machin, most small streams, unless glacially fed, are dry during much of the year.

The quality of water is good through much of the area, but in the northern and northeastern parts saline or brackish water may be encountered. In karst areas there are large quantities of underground water, while thermal springs are common in the eastern part of the Shan Plateau. In the Nan Shan, oases are the most reliable sources as the surface waters are sluggish, brackish, and otherwise unpalatable.

c. Climate

In summer the eastern border of the highlands, from the southern edge of the Gobi to the Yunnan Plateau, is exposed to the warm, moist, southeast monsoon of China, while southern and western slopes of ranges in Assam and Burma are exposed to the even wetter southwest monsoon of India. Semiarid climates predominate in the Nan Shan and at the eastern end of the Tsaidam Basin (Map 14). Scanty precipitation is concentrated in the summer months; pastures near 2,700 m in the Nan Shan do not provide grazing until June (Roerich, 1931).

Precipitation increases southward and eastward from the eastern end of the Tsaidam Basin, varies greatly with local topography, is heaviest on slopes exposed to the east, and penetrates valleys open to the east. The westward limit of the moisture penetration appears to be at the divide between the interior drainage of the Tibetan Plateau and the headwaters of the large rivers, the Huang and Yangtze draining to the east and the Salween and Mekong draining to the south. In summer, moist monsoon air aloft causes cloudiness and afternoon showers generally throughout the region.

The Tsaidam Basin has a desert climate with very low relative humidity and scanty precipitation, occurring mostly in summer. The temperature regime is unusual because of its large diurnal range, which averages about 30°F through the year. The range between the warmest and coldest months is also large, over 50 F°. The coldest month averages well below freezing; and frequently four or more months have average temperatures above 50°F.

In general, winter-dry mesothermal climates characterize the 2,000 to 3,000 m zone in the Sino-Burmese Ranges, the northern and western sides of the Szechwan Basin, and the southern fringe of the Himalaya. In some deep, shielded valleys in the Sino-Burmese Ranges, July temperatures average in the 70's. Simultaneously, while maxima

are in the 80's in the Yalung Gorge, they are generally 10 degrees lower at stations below 2,000 m farther east (Hanson-Lowe, 1941). The January temperatures in the deep canyons are raised both by shielding from the northerly winds and by foehn conditions. Again in July, mountainside stations such as Kantzu, Litang, and Chienning, with means in the 50's, do not share the warmth of the slightly lower, arid bottoms.

There is considerable thunderstorm activity in the Sino-Burmese Ranges, particularly in the southeast. It occurs both with the summer monsoon and with the spring rains which produce a secondary maximum of precipitation. July mean temperatures in cloudy areas on the outer slopes at 27° N are as low as those in clear areas 7 degrees farther north. The summer cloudiness restricts melting at high elevation, maintaining the snowline at comparatively low elevations (from 4,500 to 5,000 m) in the Sino-Burmese Ranges, in spite of their southerly latitude.

Since winter is the dry season in the Chinese monsoon region, snowfalls are light, and above 3,000 m many days may pass with little or no snowfall. As precipitation increases in spring (in some areas to a secondary maximum), snow accumulates at the higher elevations, frequently blocking passes. In the Minya Konka area, however, the maximum snowfall is reported as occurring in late summer and early fall. In 1932, for example, snow or rain occurred on all but three days between 18 August and 17 September, but the new snow accumulation at 5,000 m melted by 22 September (Burdsall and Emmons, 1935).

On the outer slopes the monsoon circulation predominates, while in interior valleys, the wind field is largely controlled by topography. The Nan Shan and the high peaks and high plains bordering the Tibetan Highlands, where winds are westerly in winter are a partial exception to this generalization. In these areas, the diurnal variation of weather is large and changes can be abrupt, creating great environmental stresses. Highlands near the Mekong-Huang Ho headwaters also are subject to great daily and seasonal weather changes. Even areas above 4,000 m, where the coldest month averages below 27°F, have at least one month with an average above 50°F. The canyons of the large rivers and their tributaries have a climate so modified from that of the highlands that it is not possible to show the variations at map scales used in this report. Villages are frequently located on upper slopes where crops fare better than in canyon bottoms, because of greater precipitation.

d. Vegetation

The north-south trend of the Sino-Burmese ranges permits moisture-bearing monsoon winds to penetrate farther into the interior of the continent than in other parts of Central Asia. Thus eastern Tibet is notably wetter than the western part, and this difference is reflected in its more abundant vegetation. Nevertheless, there are many places that exhibit a dry type of vegetation (Woodland or Steppe) because of the local orientation of slopes with respect to moist winds, or the thinness of the soil on steep slopes, or long-continued deforestation by the human occupants of the region.

In general, the lower elevations exhibit a relatively dry type of vegetation (mixed woodland of pines and deciduous trees) which gives way to evergreen forests and moist meadows above 3,000 m. The deep gorges have a steppe, shrub-steppe, or dry woodland vegetation in their bottoms and lower slopes. Where the forest has been undisturbed it is relatively dense, but cultivation and cutting have so altered this forest that many areas are covered with grass and shrubs with only clumps of trees remaining.

At the higher elevations, especially on the southern and eastern slopes, there is a dense forest - mostly of evergreen species - interrupted by meadows of tall grass. In the lower part of this forest bamboos (*Arundinaria* spp.) grow in dense thickets. It was in this forest, about 50 miles south-southeast of Minya Konka, that the giant panda was first collected by the Kelley-Roosevelt-Field Museum Expedition in 1929. This animal and the specialized habitat which it requires are found between 2,000 and 4,200 m in western Yunnan and Szechwan (Roosevelt and Roosevelt, 1929). Associated with the bamboo, and also growing above it, are forests of spruce, hemlock, beech, and rhododendron. These forests and thickets are covered with mosses, lichens, and vines, making penetration through them difficult and limiting visibility to a few yards.

The expedition which made the first ascent of Minya Konka found especially dense forests in valley bottoms at high elevations (Burdsall and Emmons, 1935). Rhododendron grows as a forest tree in some of these valleys, but near the tree-line it is no more than a shrub growing in very dense thickets.

The elevation of the tree line has been reported between 3,800 and 4,200 m, depending on the particular site and exposure. On certain mountains in East Tibet, larch (*Larix potaninii*) grows up to 3,800 m. On Yulungshan (a peak about 35 miles north-northeast of Tali, in Yunnan Province) the tree line was found between 4,150 and 4,200 m, the highest occurrence being in a region of terminal moraines at 4,250 m (von Wissmann, 1959). Between the tree line and the snow line are alpine meadows, reflecting a higher precipitation than can occur on the alpine steppes at comparable elevations to the north and northwest.

The following ranges of elevation for various types of vegetation in East Tibet are given by Gaussen and Barruel (1955) and may be regarded as average figures for the higher Sino-Burmese mountains.

Cold temperate forest (pine, hemlock, spruce, fir, larch, juniper, maple, birch, poplar)	up to 3,800 m
Subalpine forest (fir in lower zone, larch in upper)	3,800-4,200 m
Low alpine bushes (rhododendron, juniper, live oak)	4,200-5,000 m
High alpine meadows	5,000-5,500 m
Snow	above 5,500 m

The effect of these mountains as both a climatic and vegetational barrier is summarized by Gaussen and Barruel (p. 110) in these words:

> "The narrow gorges carry the jungle of low elevations into the heart of the mountains, bamboos abound and the forest is populated with numerous species and a luxuriant understory. The maximum is reached in Yunnan or in Szechwan where . . . . both coniferous and broadleaf (evergreen or deciduous) forest species grow together. But behind this sumptuous curtain of forests which rises often to 4,500 meters, the alpine belt becomes rapidly dry and steppe-like in the immense solitude of Tibet."

2. TIBETAN HIGHLANDS AND ASSOCIATED RANGES

The Tibetan Highlands, shown on Maps 17 and 18, consist of a large, roughly oval-shaped plateau interrupted by a number of high, transverse mountain ranges. It is bounded on the north by the Kun Lun Mountains (Kun Lun Shan) and on the south by the Himalayan Mountains. The principal ranges are identified on Maps 1 and 2, but reference to Maps 17 and 18 will be necessary to locate many of the place names mentioned in the following discussion. Within each of the following summaries, treating various aspects of the environment of the Tibetan Highlands and its bordering ranges, there is a progression from the Himalaya northward across Tibet to the Kun Lun Mountains. In certain of the discussions it was convenient to subdivide the Himalaya into the Lesser and the Great Himalaya, which are distinguished on the basis of elevation.

a. Configuration

(1) Lesser Himalaya

The Himalayan Mountains are composed of two distinct subregions, the Lesser and Great Himalaya. The Lesser Himalaya comprises a series of spurs from the Great Himalaya, has a length of some 2,500 km, and has a width between 64 and 80 km. One range, the Nag Tibba, includes many peaks with small glaciers and is not traversed by a river for over 160 km; it thus provides a significant barrier to travel. The Pir Panjal in West Pakistan is the highest range, with many peaks exceeding 4,500 m.

Other major ranges of the Lesser Himalaya are the Mahabarat and Dhauladhar. The Mahabarat begins west of the Tista River in Sikkim, and is traversed in the west by the Kosi and Gandak River systems in Nepal. The Kali, Gandak, Arun, and Tista rivers offer the best access routes through the range to the Great Himalaya and Tibetan Plateau. Until very recently, the principal method of transporting freight over the Mahabarat into Katmandu has been by a 25-mile aerial cableway. Crest elevations vary between 1,500 and 2,500 m. The Dhauladhar Range is the westward continuation of the Mahabarat and is traversed by the Ganges, Bhagirathi, and Sutlej rivers. The most important of these in terms of access to the interior is the Sutlej, which, from its source in Tibet, crosses the entire width of the Himalayan system.

Through most of the Lesser Himalaya, the local relief varies between 600 and 3,000 m and is greatest in those areas traversed by large rivers. As a general rule, the crest elevations are close to 2,200 m, with the bottoms of the major valleys between 500 and 1,000 m.

Throughout much of the Lesser Himalaya the major drainage is toward the South and Southeast. With the exception of the Kali, Gandak, and Sutlej Rivers (discussed under the Great Himalaya), the valleys are narrow, V-shaped, and steep-sided. Many become impassable during the spring thaw. Movement through these valleys is hampered because the narrow bottoms are clogged with large boulders in many places and have only relatively few elevated terraces. Landslides are a constant hazard, particularly during the monsoon season when vehicular movement is impossible. The region displays a fundamentally dendritic drainage pattern with such dense topographic dissection that cross-country travel is extremely tedious.

(2) Great Himalaya

The Great Himalaya is north of the Lesser Himalaya, extending over 2,400 km west of Nanga Parbat (8,129 m) to Namcha Barwa (7,756 m) in the east. Conventionally, the Great Himalaya is subdivided from east to west into the Assam, Nepal, Kumaun, Punjab and Kohistan Himalayas. The Assam section extends between the Brahmaputra and Tista Rivers, forming the boundary between Assam, Bhutan, and Tibet. This south-southwest trending segment includes the peaks Kula Grangri (7,552 m) and Kangto (7,047 m). The Nepal Himalaya traverses the area between the Tista and Kali Rivers, and its major peaks include Everest (8,848 m), Kanchenjunga (8,603 m), Makalu (8,481 m), Dhaulagiri (8,172 m) and Annapurna (8,078 m).

Between the Kali and the Sutlej Rivers is the Kumaun Himalaya. The Sutlej River separates the Kumaun from the Punjab Himalaya, which has a bifurcated trend line and lower crest elevations than the other segments. The Punjab Himalaya is not traversed by large rivers and as a consequence access is even more difficult than elsewhere.

The average elevation of the "cirque and arete" crestline of the Great Himalaya is 6,100 m. The broad open valleys north of the crest, mainly along the Tsangpo, have elevations between 3,600 and 4,800 m. In this valley region divides are broad and ill-defined.

The local relief in the zone of high peaks is between 1,000 and 7,600 m, with values between 4,900 and 5,800 m most common. In areas of such great relief, travel is restricted to the major valleys and is therefore vulnerable to attack. The smaller valleys are deep, v-shaped, and for the most part, impassable. Almost all lead to cirques or ice fields at higher levels.

The major streams which traverse the ranges such as the Brahmaputra, Arun, Trisuli, Krishna, and Sutlej rise in the broad, high elevation valleys within or to the north of the crest zone. The most characteristic feature of these large, transverse access valleys is the change from the steep, V-shaped, boulder-clogged cross-section of the Lesser Himalaya to a rather broad, U-shaped, alluvial-floored cross-section characteristic of the Great Himalaya.

A brief description of the Krishna valley in the Nepal Himalaya gives the broad characteristics of these valleys (see illustrations in Peissel, 1965). The main branch of the Krishna rises northeast of the village of Mustang (Lo Mantang) near the Tibetan border. Between Mustang and a point downstream about half-way to the village of Tukucha, the valley is broad - 1 to 3 km - and level. The stream is braided most of the year, winding back and forth across the alluvial sands and gravels and, except during periods of intense snow-melt, the numerous channels are not deep. Valley sides are steep, but have terraces which are discontinuous and alluvial fan deposits which occasionally extend some distance into the valley. Vehicular travel through the valley would be restricted during spring freshet; but foot travel would be possible along narrow valley-side trails. Because of the shifting character of a braided drainage, a resurvey of vehicular routes is necessary after each high water period. The broad, level character of the valley facilitates entrance from Tibet; however, such valleys offer a minimum of concealment except during dust storms. As it approaches Tukucha, the Krishna valley is flanked by several terrace levels which are continuous for many kilometers. South of Tukucha, the valley displays a V-profile, is steep-sided, unterraced, and contains a torrential stream. The gorge section of the valley through the Lesser Himalaya just upstream from the Gandaki Reservoir precludes the movement of vehicles. Personnel movement through this region is difficult because of steep slopes and physiological stress of high elevation. Aerial deliveries might be possible in the upper valley area.

(3) Tibet

The area of Tibet treated here extends from the north slope of the Great Himalaya to the Kun Lun Mountains, and latitudinally from the eastern flank of the Karakoram to the 98th meridian. The region can be described as a vast, high plateau, crossed by mountains of generally low relief trending in two directions, east-west and northeast-southwest. Where these trends cross, a knot of high mountains results. The plateau section of Tibet is underlain by little-altered sandstones, limestones, and shales. Granitic rocks are exposed in the southern ranges, parts of the Aling Kang Range (Alung Gangri) as well as the lesser ranges of the Chang Thang Desert. Much of central and northern Tibet has a veneer of wind-blown silts, while glacial outwash sands and gravels are locally present in some of the higher mountains.

The Chang Thang, comprising the northern and north-central parts of Tibet, is a desert of broad, alluvial valleys separated by mountains of low relief, and numerous basins with interior drainage. Peak elevations seldom exceed 6,500 m, and the range in relief is relatively small, 1,500 to 2,000 m. The southern part of the Chang Thang assumes the character of a steppe with gently sloping dome-shaped or flattened hills. Elevations range between 4,300 and 5,000 m. The mountain ranges which cross the Chang Thang are little dissected and have sparse or no vegetation.

From the Dupleix Range (Monts Dupleix) north to the Kun Lun Mountains, cinder cones, lava plateaus and escarpments dominate the terrain. Most mountain ranges can be easily crossed by shallow passes, although the closely spaced, narrow, steep-sided valleys and ridges of the dry basins north of Karakoram Pass present a major obstacle to vehicular or troop movement.

The southerly Nyenchen Tanglha Range forms an almost unbroken chain of little-dissected, snow-capped peaks rising from 5,000 to 7,000 m. Travel through this range is possible through passes which vary in elevation between 5,000 and 6,000 m. River valleys leading to these passes are narrow and steep-sided, usually floored with varying amounts of glacial outwash - some of which may be terraced. The area south of the Dupleix Range is broken by a disarrayed group of hills and complex, narrow valleys which prevent any large-scale or rapid vehicular movement. East of the Dupleix Range in southwest Tsinghai is a vast, gently rolling, swampy upland where elevations seldom exceed 4,300 m. In this area vehicular traffic is restricted to the better-drained uplands.

Central Tibet*, the area between the Nyenchhen Thanglha and the Monga Kang Range (Monga Gangri), is one of internal drainage with desert-like aspects. The eastern segment contains some of the largest lakes in Tibet. These lakes are situated in broad, flat basins surrounded by closely spaced, highly dissected hills or steep, sharp-peaked mountains.

Movement of vehicles and troops on the Tibetan plateau generally would not prove difficult. Passage in the southern ranges is more difficult, particularly if movement is from the south where the valleys are deeper, narrower, and prone to landslides. The dry basins of Tibet provide a wide variety of landing and drop sites.

(4) Kun Lun

The Kun Lun Mountains extend 1,300 km from the Muztagh Ata Range eastward to the south side of the Tsaidam Basin. This parallel and sub-parallel system of ranges varying in width from 40-90 kilometers forms the northern border of the Tibetan Plateau. As the Kun Lun passes from Tibet into China it loses the form of a great chain and breaks up into numerous minor ranges much like those of the Hindu Kush in Afghanistan. Maximum elevations are on the order of 7,000 m. Much of the crest area of the western and central Kun Lun is above the permanent snow line of 5,000 m.

In the Kun Lun there are a few long, broad, high-elevation valleys which parallel the crest to the south. The rivers, instead of converging within the ranges like those of the Himalaya, flow directly down from the snow fields to the broad alluvial fans that border the Takla Makan desert. Exceptions are the Charchan and Keriya rivers which drain areas south of the main crest.

West of Hotien (Khotan) the outer flanking ranges are highly dissected by a labyrinth of narrow, branching canyons which are nearly impassable to all forms of movement, particularly during freshets when they carry foaming torrents. The major drainage is via the Yarkand and Qara Qash (Kara Kash) rivers (Map 19).

* This large area is termed the Gandisyshan Transhimalaya by Yusov (1959).

East of Hotien the northward draining streams debouch from deep, narrow canyons, at about 13 km intervals, onto the alluvial fans and bajada slopes marginal to the Tarim Basin, where they flow for short distances in narrow, deep washes before disappearing. Most of the stream valleys draining the north slope are terraced and those that arise in passes (usually over 5,000 m) are easily traversed. It is not likely that vehicles can negotiate many of them until roads have been constructed.

The major rivers of the central and eastern Kun Lun, the Keriya (at about 81° 30' E) and the Charchan (farther east and north of area shown in Map 17), which drain from the inner ranges, have deep, steep-sided, and impassable canyons. The south slope of the Kun Lun is gentle, with few streams. These drain to the saline lakes of the Soda Plains (Aksai Chin) and Chang Thang desert basins. In general, the Kun Lun offers much less of an obstacle to vehicles and troops moving into Tibet than do the Lesser and Great Himalaya.

b. <u>Water supply</u>

In the Lesser Himalaya, runoff is highest from June through October when peak moduli may run as high as 100 liters/sec/km^2. The annual average approximates 52 liters/sec/km^2, but a figure of 39 liters/sec/km^2 is probably more realistic when evaporation is concerned. These values are subject to wide variations from area to area, especially below 1,000 m. Because of the large amount of precipitation in the region (see Fig. 8), no problem of water availability should be encountered except possibly in first and second order streams during the dry season. Water quantity will be high, but treatment is advisable on most streams because of habitation.

Peak flow in the major valleys of the Great Himalaya occurs during early summer when glacier and snowmelt is greatest. Diurnal fluctuation of water level occurs during the melt period with streams being lowest during the early morning hours and highest in late afternoon and early evening. Water in the major streams is heavily laden with silt and is generally unsuitable for human consumption or as a meter coolant.

The smaller streams may go dry during the summer, although generally sufficient fresh water is available. Limited supplies of ground water are available in alluvial fans, but use of existing dug wells should be avoided because of the likelihood of contamination.

The rivers of northern and southern Tibet, though different in valley type, both show seasonal water level fluctuations. Two high-water stages occur in both regions, one in early summer during snow melt and a second in late summer in response to thaw of mountain glaciers. This regime is somewhat muted in July and August in response to maximum temperatures and high rainfall.

Because of the interior drainage of northern Tibet, river systems are largely patternless, i.e., streams in the same area may flow in opposite directions. The mountain rivers of northern Tibet either flow within the mountains throughout their entire course or rise in the mountains and fall steeply over rocky beds, eventually discharging onto the flat highland surfaces and flowing quietly through broad alluvial valleys. Those not fed by groundwater may dry up in autumn. In all cases, permanent streams freeze to the bottom in winter.

The southward increase in rainfall is reflected in the runoff moduli as follows: Northern Chang Thang: 3.2 liters/sec/km^2; Southern Chang Thang: 6.3 liters/sec/km^2; Central Tibet: 9.5 liters/sec/km^2. In general, adequate supplies of fresh water can be relied upon only in the mountain areas. The large, interior-drainage lakes of the Plateau are shallow and often saline. Some contain water only during the spring freshet; others show a shift from brackish to saline as summer progresses. Because of its salt content, this water is not suitable for either human consumption or as a coolant for vehicles.

Throughout the Kun Lun, reliable sources of fresh water will be a problem except during the spring freshet, and from streams originating in permanent snow fields. The spring freshet on the north slope may make many potential access routes impassable for a short period. Most of the small streams dry up during the summer and fall, while streams of intermediate size contain a small flow within the mountains. High level swamps and lakes, except those receiving water from snow fields, will be brackish or saline.

c. Climate

Although the southern slopes of the Himalaya are subject to heavy precipitation at lower levels, the Tibetan Highland is essentially a cold, dry desert. Precipitation is less than 10 inches over most of Tibet, and the mean temperature for the warmest month is below 50° F. The greatest

stress is that due to decreased atmospheric pressure, but the low temperatures, high winds, permanent snowfields, and abrupt weather changes create additional stresses when superimposed on a complex terrain.

In areas not directly exposed to moist air masses, precipitation usually occurs in the form of afternoon showers. Its occurrence depends to some extent on local moisture sources, but primarily it results from the presence of moist air aloft subsequent to orographic lifting. Moist monsoon air penetrates through the north-south oriented valleys in Assam and Burma, creating cloudiness and afternoon showers or thundershowers in Eastern Tibet. However, moist air does not reach shielded locations, such as Gartok in the lee of the western Himalaya, because the moisture is precipitated on the intervening, unbroken ranges of the Punjab Himalaya. Thus many valleys and high basins are arid, particularly in the lower parts. Slopes around large inclosed depressions, such as the Tarim Basin, are arid since they are not exposed to moisture-laden air borne by the general circulation.

In the Chinese provinces of Tsinghai, moisture penetrates to about 35° N, even in the higher areas (Tajih, Sewukou, Yuyujihpen). Although precipitation measurements are not available at these higher stations, the relative humidity and cloud cover show the presence of moist air. The westward limit of its penetration appears to be the watershed between the interior drainage of the Tibetan basin and the headwaters of the large rivers which drain to the south and southeast. Precipitation throughout the whole eastern region is concentrated in the summer months.

The elevation of the snow line is low where precipitation is abundant and where summer cloudiness limits melting, as on the southern ranges of the Himalaya. On the northeastern, arid slopes of the Tibetan Highlands, 8 to 10 degrees of latitude farther north, the snow line remains at about the same elevation as in the southern ranges. In the arid regions, the snow line is higher on southerly slopes, where solar radiation is most effective in causing ablation. West of about 90° longitude in the Tibetan Highlands and on the Kailas and Nyenchen Tanghla Ranges of the Trans-Himalaya, the snow line lies above 6,000 m (Fig. 5).

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Orientation of valleys influences their temperature, wind regime, and snowfall. Differences due to extent of exposure to moist air are shown by snow depths of 29 to 36 inches near 5,000 m on the outer side of the Sikkim-Nepal ridge, compared with 19 to 20 inches on the inner side (Dhir, 1953).

Storms are sudden and violent both in the Tibetan Highlands (Hedin, 1909) and in the Himalaya (Wager, 1934). Snowfall, although concentrated in summer when the monsoon provides moist air, may occur in any season as local snowstorms at altitudes above 4,000 m in the Himalaya. Névé depths of 15 to 75 feet are reported (except on the steepest slopes) on the high mountains of the Nepal Himalaya (Dhir, 1953). On the southern slopes of the Himalaya, east of about 80° E longitude, a single pronounced summer precipitation maximum occurs. Fog is frequent in valleys and on lower slopes. In the Tista Basin (about 28° N, 88° E), a snow survey by the Indian Government indicated winter snow cover down to about 3,200 m. Lachen, at 2,700 m, had six feet of snow cover in February-March (Dhir, 1953).

Snow and hail showers occur frequently in the Tibetan Highlands, but water content is low. Snow accumulation is small and disappears quickly due to the combination of intense solar radiation, little cloudiness and low relative humidity. The onset of snow and hail showers is abrupt, with strong wind gusts, low visibility and rapid temperature fluctuations.

On the southern slopes of the Himalaya between 3,000 and 4,000 m a large portion of the precipitation is in the form of snow. In the Tista Basin of Sikkim the winter snow cover line extends down to about 3,200 m (Dhir, 1953). Thunderstorms with snow have occurred in April at 3,750 m.

Snow usually does not remain long on the ground in the Tibetan Highlands. However, several feet of snow were reported at Nagchhu Dzong (Heiho) near Adag Mamar in 1917 (Roerich, 1937).

Above 4,500 m on Mount Everest one to two feet of snow may fall overnight. At this elevation, snowfall may occur in any month of the year. Light precipitation with low water content is to be expected with extreme cold, but contrasts in snowfall do exist, due to variation in the supply of moist air available. The aridity of the Tibetan Highlands is due to their distance from large moisture sources and the impediment which the Himalaya present to the flow from these sources.

Evaporation and sublimation resulting from strong winds, dry air and high solar radiation, remove the snow from most of the upland, except for the passes, within a short period after it falls. While the lack of snow cover makes travel easier, it can lead to dangerous unpreparedness for the severity of the sudden snowstorms, as seasoned explorers have discovered (Hedin, 1909). "Despite high elevation, it is possible to suffer greatly from heat in inclosed basins such as the Garmo Glacier in the Pamirs" (Siesser, 1962-63). Light winds and intense solar radiation reflected from the glacier surface and surrounding snow-covered slopes can radically change the expected weather conditions so fast that the effect can be enervating.

Precipitation decreases westward along the southern border of the Himalaya, but stations exposed to the monsoon, such as Dalhousie, Mukteswar, Murree, and Mussoorie, receive from 55 to 85 inches. Thunderstorms, many with hail, are frequent. Much of the Tibetan Highland has steppe or even desert climate with double precipitation maxima in spring. Even though the precipitation total is small, there are many wet and cloudy days.

Precipitation in the lee (north slopes) of the Himalaya has a summer maximum. It is normally light and varies greatly from year to year, depending upon the extent of penetration of the monsoon through the deep valleys. For example, annual precipitation at Lhasa (3,685 m) totaled 198 inches in 1936, while the average for 14 years, excluding 1936, was 17 inches (Hsu, 1946). Lhasa has little snowfall, about 10 days per year.

In many shielded valleys, precipitation results from convection and from mountain-valley wind circulations. Some of these valleys are very dry. The lower limit of vegetation on their slopes is determined by aridity and the upper limit by cold (Schweinfurth, 1956). The most arid part of Tibet is the Chang Tang, which receives generally less than 5 inches of precipitation per year.

The valleys of the Tsangpo (upper Brahmaputra) and its tributaries in the lee of the Himalaya have a dry steppe climate. Together with great variability in precipitation from year to year, such stations as Lhasa, Zhikatse, and Gyangtse also experience large daily temperature range. Under conditions of high solar radiation and low wind speed, temperatures differ greatly in the sun and in the shade (Ekholm, 1904).

In the Kun Lun Mountains along the northern border of Tibet, precipitation is very light except on the western extremeties. The steepness of slopes results in rapid run-off, particularly on the northern slopes. Deep but not impassable snow has been encountered on the north side of the Suget Pass (north of Karakoram Pass in the Aghil Mountains) in September (Roerich, 1931).

In both northern and western Tibet there is considerable dust, despite observations that show "very low visibility" occurring less than 1% of the time (USAWS, 1945). The frequency of occurrence of low visibility, however, is no measure of the extent of the extremes nor abruptness of their onset.

Weather in the high passes is severe; here the exertion of climbing in the rarefied atmosphere, colder temperatures, strong winds, and snow and ice are stress factors to consider.

Summer winds in the Tibetan Highlands and in the 4,000-5,000 m zone immediately bordering them, are largely under control of local topography, or of the monsoons where they penetrate. High exposed locations have westerly winds in winter, but some locations are subject to considerable local terrain control in all seasons. Wind-frequency tables for stations in the eastern parts of the Tibetan Highlands show a combination of influences from the summer monsoon, the prevailing westerlies of winter, and the diurnal mountain and valley circulations.

At 4,000 m January temperatures average near 20°F in the east and south, about 15°F in the west, 10°F at the northern edge of the Tibetan Highlands, and less farther north. Nocturnal temperatures and daytime shade temperatures are, however, by no means so strongly dependent on elevation in January as they are in July. Even in July, when skies are clear and cold air drains into basins or enclosed valleys, nights are cold in the lower spots due to radiational cooling. Minima of 5 to 10°F have been reported.

Precipitation is extremely light, above 5,000 m, due to the absence of monsoonal influences. Even on slopes exposed to the monsoon, there is much less precipitation at these levels than at lower elevations with similar exposures Two supplementary sets of precipitation observations in this zone in the Mount Everest area totaled 17.7 inches for the year (F. Müller, 1958; Pugh, 1962).

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Continuous observations through one winter and spring near 5,700 m on Ama Dablam (south of Mt. Everest) yielded the following data (Pugh, 1962): average January temperature, 9.5°F; April, 19.4°F; absolute minimum, -16.6°F; winds, W to NW, about 22 knots, with calm for three weeks in April; maximum, 35 kt, gusts to about 50-60 kt; average relative humidity, 25%. Monsoon storms ended at the beginning of October. There was little cloudiness, but frequently cumulus form below 5,000 m in the afternoon. Note that temperatures were higher than the predicted 500 mb level free-air temperatures of 7°F for January, and 10°F for April at this latitude; the height of the 500 millibar pressure level averages about 5,570 m (Goldie et al, 1958). January free-air temperatures range from 7°F along the southern Himalaya to -32°F in the Tien Shan; July temperatures range from 28° (30°F, Rangarajan, 1963) in the south to 16° in the Tien Shan and 10° north of Lake Balkhash.

About 3 percent of the Tibetan Highland lies above 6,000 m. A climate where mean temperatures in the warmest month do not average above freezing is to be expected almost everywhere, and minimum temperatures here are extreme.

Recent analysis of upper air observations shows a diffuse, east-west, warm belt in the upper troposphere over the continent of Asia from 25° to 30° N latitude, with a -10°F free-air temperature in July near the level of the summit of Mount Everest (Rangarajan, 1963). This is 3 to 5 degrees warmer than shown on most upper level maps. An average of about -40°F may be expected in January, and -36° in April (Goldie et al., 1958; NACA, 1962). Most ascents of Mount Everest have been attempted between April and early June, when temperatures are higher and winds lighter than in winter, and snowfall lighter than during the summer monsoon. Pugh (1957) attributes the choice of this particular season to the fact that the observed summit temperature (-27°F) and interpolated pressure (333.3 mb) were both higher than anticipated. The standard pressure and temperature should not be applied at all altitudes without modification (Kay, 1958), nor can the seasonal mean be expected on a particular day with no regard to the scatter of the individual observations. Pugh experienced higher pressures than shown by the standard tables, both at the lower camps, where it was measured, and at higher locations, where pressures were extrapolated using temperatures measured at the sites.

d. Vegetation

(1) The Himalaya

In the 1,500-mile extent of the Himalaya the vegetation exhibits pronounced changes both altitudinally and laterally. The high degree of relief in the Himalaya is responsible for a distinct zonation of vegetation with increasing elevation, while the increasingly arid climate toward the north and west causes a change from moist evergreen forests in the southeast to steppe or dry woodland at equal elevations in the northwest. Typical of the contrast between east and west is the fact that bamboo is a common element of the forests in the eastern Himalaya but occurs only rarely in the western part.

The vertical zonation of vegetational types recognized by Champion (1935) has been followed by many other authors. In order of increasing elevation, they are generally in the following sequence in the central Himalaya (at about 84° E Lat.): (1) tropical moist deciduous (sal) forest, (2) subtropical pine forest, (3) moist temperate forest, (4) dry temperate forest, (5) alpine vegetation. The first of these types is entirely below 2,000 m, while the second exceeds 2,000 m only on southerly fringes. The remaining three types are shown on Map 6 as Moist Evergreen Forest, Dry Forest and Woodland, and Thickets and Meadow, respectively, although a part of the "alpine" type would fall into the Steppe category where growth is sparse.

At the eastern end of the Himalaya, in Assam and northern Burma, Champion (1936) recognized a "northern wet temperate forest" between 2,000 and 3,000 m. This in part is the type that Stamp (1930), writing of Burma, termed "mountain vegetation", but its moist evergreen character is unmistakable from Stamp's description:

> "The mountains of the north are clothed with dense forest, consisting largely of rhododendron in the higher parts, but of pines in some areas."

At the opposite end of the Himalaya, in northwestern India and Kashmir, moist evergreen forests are absent and the Dry Forest and Woodland types are more prominent above 2,000 m. It should be noted, however, that dry valleys can be found throughout the whole extent of the Himalaya, even in the eastern part where the climate generally is humid. It is not uncommon to find a dry valley bottom with steppe vegetation between slopes covered by moist evergreen forests.

The vertical zonation of vegetational types in the central Himalaya according to altitudinal and moisture gradients is shown by Figure 23B, which is adapted from a diagram by Kawakita (1956). The altitudinal ranges of the principal forest species in central Nepal clearly show the importance of the 2,000-meter level as a vegetational boundary: none of the "tropical" species of trees extend above this elevation except the chinkapin, *Castanopsis indica,* which exceeds it by only a hundred meters, while none of the coniferous species characteristic of the higher elevations grow below the 2,000-meter elevation. The species exhibiting the widest altitudinal range are the evergreen oak, *Quercus semicarpifolia* (from 2,000 to 3,300 m), *Pinus griffithii* (from 2,100 to 3,800 m), and *Rhododendron arboreum* and *Rh. wrightii* (from 1,500 to 3,300 m). Excepting these, most of the tree species that are characteristic of either the "subalpine" or the "temperate" zone do not range very far beyond the elevational limits of their respective zones.

Kawakita draws the line between his Subalpine and Alpine zones (i.e., the tree line) at 3,900 m in the central Himalaya. The trees characteristic of the Subalpine zone - *Pinus griffithii, Larix griffithiana, Abies spectabilis, Juniperus wallichiana, Betula utilis,* and *Rhododendron campanulatum* - all reach their upper limit at or slightly below this level. There is one conifer, however, a dwarf juniper *(J. squamata)* that grows up to 4,200 m. These limits agree fairly closely with those given by Schweinfurth (1957), who reports the upper limits of trees in the Himalaya at various altitudes from 3,600 to 4,000 m; the highest tree nearly everywhere is the birch *(Betula utilis),* which has been reported at elevations up to 4,200 m.

A very important aspect of the vegetation of the Himalaya is the extent to which it has been altered by human activities. In Nepal, for example, the Mahabharat or Lesser Himalaya is intensively cultivated up to 3,000 m, despite the steepness of the ground, and it is estimated that only one-third of this area remains in forest (Robbe, 1954). According to Kawakita (1956) the 2,000-meter level is the elevation at which natural forests begin to appear fairly commonly in central Nepal, the greater part of the land below this elevation being utilized for cultivation. West of the Gandaki Reservoir, Kawakita found the lower limit of natural forest at about 2,200 m on the eastern side and at about 2,400 m on the western side. There has been widespread destruction of forests in

2 [illegible]

this region, both for firewood and to create pasture land. Further north, in the Himalaya proper, frequent forest fires have been reported in late May in the valleys of the upper Marsyandi and the Dudh Khola (northeast of Annapurna); secondary forests of pine *(Pinus griffithii)* in these valleys probably owe their origin to forest fires.

Even at the higher elevations, where forests are discontinuous or absent, the vegetation has been considerably altered by grazing. The effect generally has been to decrease the relative abundance of the more palatable grasses, to eliminate reproduction of trees, and in some places to increase the area of barren, unusable land.

(2) Tibetan Highlands

Many small-scale vegetation maps show almost the entire area of Tibet as covered by "steppe" or some similar type. Such representations give an impression of a vast area that is relatively homogeneous in vegetation and aspect. This impression is erroneous for two reasons. First is the considerable variation in mean annual precipitation within Tibet, with a general decrease from southeast to northwest. Second is the fact that Tibet is crossed by a large number of transverse mountain ranges, some of very considerable height. Since there is no significant vegetation above about 6,000 m, there are large areas, even in southern Tibet, that must be classified as barren. In a region where the growing period is short and the conditions vary widely from year to year, there may be a marked difference in the appearance of the vegetation when seen at intervals of only a few weeks, or even at the same date in different years.

One of the best summaries of the geography of Tibet, that of Yusov (1959), recognized the following categories of vegetation (or its absence):

(1) Eternal snows and glaciers
(2) Gravel-pebble desert
(3) Vegetation of high mountain deserts
(4) Vegetation of high mountain steppes
(5) Meadow-steppe vegetation
(6) Temperate zone forest
(7) Tropical and subtropical forests
(8) Cultivated vegetation (agricultural regions)

The first of these categories is generally above 6,000 m. Most of Tibet is shown in Yusov's categories (2) to (5), each occupying an east-west band arranged from north to south in order of increasing moisture. The fourth category (high mountain steppes) is the most extensive of these four.

When considered in terms of the categories shown in Map 6 and the criteria used in their differentiation, some consolidation of these types is possible. Areas of "Negligible Vegetation" include not only those that are perpetually snow- or ice-covered, but also bare rock and the gravel-pebble deserts of the northern Chang Thang, where plants are so few and widely spaced as to have no practical significance. On the other hand, even Yusov's "high mountain deserts" have a growth of grass and other herbs during a brief period each year and, consequently, they are visited by nomadic herdsmen. Because they provide some forage, however limited, that could be of use to small military parties as well as to the indigenous population during part of the year, they can be regarded as Steppe. The "meadow-steppes" and some of the "temperate forests" in Tibet, however, have a similarity to the Thickets and Meadows in other parts of the study area, although the trees tend to be small and confined to the valley bottoms. This seasonal character of the vegetation in a large part of northern Tibet is well illustrated by the following passage from Yusov (p. 130):

> "In summer, when the rains come, and snow and ice melt in the mountains, favorable conditions arise in the Changtang for the growing of grass; the soils are saturated with moisture, the water table rises, some lakes even turn fresh, . . . In the autumn, when the thawing of the snows and the rains come to an end and the dryness of the air increases, the grass dries out and the landscapes become completely desert-like.'

Conditions such as those described above seem to prevail in a large part of the Chang Thang, which may be alternately a desert, a steppe, and a region of relatively lush meadows in different seasons or years.

(3) Kun Lun Mountains

The Kun Lun Range is probably the most barren of any in the entire study area. Particularly on its northern slopes, it is known for its almost complete absence of vegetation. At the foot of these slopes is a wide zone of barren piedmont gravels, while higher the slopes are deeply eroded and all but lacking in vegetation of any kind. Only on the southern slopes of the range is there a sparse growth that reflects the seasonal melting of snows on the higher parts of the range.

3. THE PAMIR KNOT AND ASSOCIATED RANGES

a. Configuration

The Pamir Knot is an area where several high mountain ranges converge - the Karakoram and Hindu Kush on the south, the Muztagh Ata on the east, and the Tien Shan on the north. (Maps 19 and 20). The highest point in the area is Communism Peak (Pik Kommunisma, 7,493 m), formerly known as Stalin Peak (Pik Stalina) and so designated on Map 19. The Pamir Knot and the Karakoram-Hindu Kush are considered separately in the discussions below.

(1) Pamir Knot

The Pamir area has been called a plateau, but in reality it is composed of a series of nearly parallel, high, broad, alluvial valleys (pamirs) separated by mountain divides. The average elevation of these valleys is 3,600 m and that of the flanking mountains is 4,600 m. The majority of the valleys trend nearly east-west.

The rock types found in the Pamir area range from crystalline to slightly altered or unaltered sandstones, shales, and limestones. Shales and limestone form much of the high relief of the ranges. Salt and coal beds are found among the various strata. The valley floors are made up of gravel and sand deposits; some are recent alluvium, some emanate from landslides, and others are glacial moraines.

In the central portion of the Pamir region the local relief is relatively small, probably not exceeding 1,000 to 2,000 m. To the west, where valley bottom elevations are much lower, values increase to nearly 4,000 m. The western flank of the Pamir area is highly dissected by narrow, steep-sided valleys, some of which contain discontinuous alluvial terraces. A few of these valleys provide access to the high-level pamirs, but their narrow defiles preclude vehicular ingress. The broad, gentle alluvial slopes which flank the pamirs may be cut by deep washes and canyons where landslides are also common.

There is easy access to the pamirs along the alluvial terraces of the Ab-i-Panja River valley to the Great Pamir. Approaches from the east and north are difficult, because here deep, narrow canyons and valleys provide the only access through the flanking ranges. The pamirs themselves provide little hindrance to large scale movement.

They can be described as smoothly-contoured troughs framed on both sides by snowcapped mountains. The streams which flow in the Pamirs have not cut deeply into the sand and gravels and they wander sluggishly in a braided fashion across the valley floors.

The major east-west-trending pamirs range in length from 40 km (Rang Kul) to 200 km (Sarez), in width from 1 to 25 km, and are approximately 30-40 km apart. Bottom elevations range between 3,000 and 4,000 m and low points in each pamir are commonly occupied by a lake or dry lake bed. The largest of these is Kara Kul which occupies almost the entire Karagash Pamir.

The two north-south-trending pamirs are in most respects similar to the others. They are longer (110 to 130 km), have more sinuous alignment, and lack lakes of any size. They lie to the east of the east-west trending group and separated from it by a mountain range called the Sarykol.

In the Pamir area, just as on the Tibetan Plateau, there are few major obstacles to movement once the difficult approaches have been traversed. Thus from the standpoint of mobility and defense, the terrain favors the defender. The east-west-trending pamirs are subject to sudden strong winds and dust storms which are hindrances. These are not found in the major north-south-trending valleys.

There is a substantial area covered by glaciers in the Pamirs, shown on Map 21. The total area of ice and firn is estimated at 8,041 square km (American Geographical Society, 1958, Part 7a).

(2) Karakoram-Hindu Kush

The belt of the Karakoram-Hindu Kush extends in an arc over 1,000 km long from its eastern terminus at Lake Ngombo, Tibet, northwest through Kashmir, westward through northern Pakistan to the Afghanistan border, and thence southwest into Afghanistan, terminating in the Koh-i-Baba Range.

The major drainage is tributary to the Indus River. The region also has a northward drainage to the Tarim Basin via the Yarkand River. The general elevation of the valley floors is higher than in the Great Himalaya, and stream density is greater. The division of the valley cross-sections into a "V"-shaped lower segment and a broad U-shaped upper segment is not as apparent as in the Himalaya; however, glaciers and ice fields are more extensive.

The Karakoram Range is high and perhaps more impressive than the Great Himalaya because of the intense glacial action. The range is highest in the east where local relief is generally between 1,500 and 3,200 m, decreasing westward to between 900 and 2,700 m in the western Karakoram and in the Hindu Kush. Total relief from the summit of K-2 (Mt. Godwin-Austen) down to the Sudus River, just 100 miles south, is nearly 7,000 m.

Particularly in the Karakoram Range, most of the large rivers and some of their tributaries flow in rather broad "U"-shaped valleys, whose headwater valleys are generally above 3,000 m. The streams are usually braided and flow on glacial outwash sands and gravels. Many of the valleys are terraced. In the Karakoram especially, most of the headwaters originate at glaciers (Fig. 22) and have gentle gradients.

Most of the large rivers and their tributaries are subject to severe and sudden flooding, which usually is the result of sudden releases of glacier or moraine dammed lakes. Rock falls and debris avalanches are common in all valleys. Unique to the Karakoram are the broad lateral drainage channels which run parallel to the glacier tongues, between the ice and the rock walls. These channels are flat floored, ranging in width from tens of meters to several hundred meters, and contain braided streams flowing with gentle gradients over alluvial and outwash gravels. Such channels are longest and most distinct at the foot of south-facing slopes marginal to east-west trending glaciers. Though in some cases they provide easy access ways to passes, all are subject to great diurnal variations in stream height.

The Hindu Kush are for the most part much less rugged than the Karakoram and display an arid morphology. Individual ranges are flanked by alluvial fans and talus. The major valleys are terraced and usually broad near the head waters. Where they pass through the ranges they become canyons. Movement through the Hindu Kush, particularly in the Afghan Hindu Kush, is relatively easy. The only serious impediments to movement are the numerous dry washes which cut the alluvial fans and pediments. In the Karakoram, personnel and vehicular movement would be restricted to the major stream valleys such as those of the Indus, Shyok, and Nubra systems. Periodically, movement will be rendered hazardous by possible landslides and flooding.

In broad valley bottoms coarse gravel and sand are overlain in many areas by fine silts. In general, the coarser materials are above the valley bottoms and near the glaciers.

b. Water supply

Perennial streams and lakes occur in the central and eastern section of the Pamir region. Many of these are fed from glaciers and have a large discharge during the spring freshet. Rivers of the individual Pamirs have low gradients and are interrupted or bordered by swamps. Flooding during the freshet probably occurs along most of these rivers. The more arid eastern section has few perennial streams and many of the smaller streams go dry during the summer months.

In the Karakoram all glacially fed streams show both seasonal and diurnal high water stages. Channel shifts and local deepening and filling of channels usually accompany high water stages in the braided drainage. Infrequent catastrophic flooding occurs, particularly in the Shyok drainage.

The water from the major drainages, at least, will be heavily laden with silt and clay during the highwater periods. In the melt period the quantity of fine sediment is least during the early morning hours. In the desert ranges of the Hindu Kush, water shortage and saline or alkaline water can be expected.

c. Climate

Moist air from the Mediterranean and North Atlantic reaches the western Pamirs, particularly during winter and early spring, penetrating only weakly into the deep west-east-oriented valleys. The high valleys (pamirs) and all the eastern slopes are very dry, with strong west winds and blowing dust. In spite of the aridity, however, swampy areas occur around the lakes. The line dividing the western Pamirs, which have considerable winter snow cover, from the eastern Pamirs, with almost none, corresponds closely to the 10-inch isohyet. In some areas it is barren just below the firn line. Summer temperatures above 80°F occur in the deep, protected valleys on the western side of the Pamirs.

On the western side of the Pamirs, maximum precipitation occurs just below 2,000 m (Mirov, 1951). In winter, snowfall increases with elevation: there are 127 snowfall days at Obigarm, at 1,710 m. Annual precipitation totals more than 50 inches at comparable elevations among the mountains which lie astride the Alai Valley (Vakhsh River) in the vicinity of 39° 30' N, while steppe and even desert conditions are found further south. The high valleys and all the eastern slopes are very dry, with strong west winds and blowing dust. In spite of 51 snowfall days at Pamirsky Post (3,653 m) near Murgab, snowfall is very light and does not lie long on the ground because of the dryness of the air. The greatest snow accumulation in three years of record was less than 2 inches. Naryn, 1,600 meters lower and 250 miles farther north, has had 12 inches of snow resulting from 72 days of snowfall (Rubinstein, 1931). Winter inversions stay below 2,000 m, and temperatures in the highlands therefore decrease as elevation increases in both summer and winter. Very warm summer temperatures, above 70 or 80°F occur in the deep, protected valleys and in the Sukhan (Termez) Basin.

In the Afghanistan parts of the Hindu Kush, precipitation is light occurring mostly in winter and usually as snow at high elevations. This snowcover is quickly lost in the spring except in a few areas. The northeastern parts of the Hindu Kush have considerable snowfall and a climate only slightly less severe than that of the Karakoram. High peaks in the Karakoram are reported to be drier than those in the Nepal and Punjab Himalaya. About once in 50 years the monsoon does reach the Karakoram with resulting heavy snow for short periods.

Precipitation is light in shielded sites such as Leh. Parts of Kashmir that have steppe or even desert climate may have many damp and cloudy days in spite of the low rainfall. Considerable winter snow falls in northern Kashmir, but there is less summer precipitation than in the Himalaya. Local temperature inversions are prevalent in the high inclosed valleys and can be of strong intensity. One of the lowest temperatures at a long-record station (-49°F) oucurred at Dras, at 3,066 m in a small oval valley at 34-1/2° N (India Meteor. Dept., 1953).

Afghanistan has steppe climate in the east and desert in the west. Much blowing dust is encountered, and, at low elevations primarily below 2,000 m, violent dust storms and the simoon occur. The latter is a very hot, very dry wind, preceded by a cold wind. Kabul has 20 snowfall days annually on the average, but there is great variation from year to year.

In the Pamirs, the perennial snow line lies within the 4,000- to 5,000-meter zone. The western slopes of the north-south ranges and the southern slopes of the Alai Range have considerable snowfall, but less total precipitation than the 50-60 inches that fall on the lower exposed slopes near 2,000 m. Autumn is the driest season at all levels; a spring precipitation maximum is characteristic in the lower zones, and summer showers occur more frequently in the higher zone.

Both the Mustagh Ata Range and the high Pamirs are very dry. Observations were made from 14 June through 26 September 1958 at a 4,200 m site in the eastern Pamirs (Tadzhikov, 1963). In July temperatures averaged 50°F and minima below freezing were recorded. The maximum diurnal range of 35°F occurred in September. Relative humidity averaged 33%, but ranged 93 percentage points in July and August. Sudden, brief, violent storms occurred occasionally. Wind speed was most frequently 3 to 10 knots, with a maximum near 30 knots. Graupel was the most frequent type of precipitation in showers, although one hail stone 0.2 inch in diameter was reported. Snow accumulation of 2 to 3 inches occurred twice. Cloud cover was less than 20% on 29 of the 105 days, and 44 days were overcast. Wind was frequently accompanied by dust clouds from various directions.

d. Vegetation

(1) Pamirs

The Pamirs have a treeless surface in which meadow, sparse steppe, and barren ground are all present. The vegetation of the Pamir Plateau is described as follows by Berg (1950, p. 186):

"The vegetation is sparse, and the mountain slopes, as well as the valleys, are far from covered with verdure. Among the characteristic plants are the small squat halophytic undershrub, Old World winter fat (*Eurotia ceratoides*, native to the stony desert of the Pamirs), which is used for fuel; *Acantholimon diapensioides*, which is flattened in the form of a cushion, and rise 3 to 5 cm above the stony soil; the cushion-shaped legume, crazyweed (*Oxytropis*); the high mountain polyn, *Artemisia skorniakovii*; and the feather grass *Stipa orientalis* . . .

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Lichens and mosses grow on the "Takyrs";* sometimes they cover as much as half the surface. On the solonchaks there are very few plants; one of them is the annual crucifer *Dilophia ebracteata*. In moist places in the valleys there are cobresia meadows; solonchak sedge meadows are common. But there are alpine meadows as well."

Only in the western part of the Pamirs which has a somewhat more abundant vegetation than the eastern part are trees found. There are birch and cottonwood trees along the streams, and open forests of junipers on the slopes. Orchards of apricot, pear, and mulberry are cultivated in valleys up to an elevation of 3,500 m (Mirov, 1951). The tree line in these mountains varies from 3,400 m to 3,600 m (Hermes, 1955).

(2) <u>The Karakoram</u>

In the Karakoram the zonation and types of vegetation are much like those of the western Himalaya. The pattern of vegetation types in the northwestern portion of this range, in the vicinity of the Hunza Valley and Rakaposhi Peak, is shown on Map 23A as mapped by Paffen (1956). In this particular area, the Steppe largely consists of artemisia, while Dry Forest and Woodland is similar to steppe but has a scattered growth of Juniper trees *(J. semiglobosa)*. In a few localities the Dry Woodland consists of *Pinus gerardiana* or *Quercus ilex*. The Moist Evergreen forest contains denser stands of juniper or spruce *(Picea morinda)*, pine *(Pinus excelsa)*, or fir *(Abies webbiana)*. At higher elevations the Thickets and Meadows include alpine meadows and thickets of birch and mountain-ash.

In the middle Karakoram the tree line is found at 3,500 to 3,600 m (Hermes, 1955). This is somewhat lower than in the Himalaya, and there is a wider altitudinal gap between the tree line and the snow line, which has an average elevation of about 5,500 m.

*Takyr (Russian): "The flat-floored bottom of an undrained desert basin becoming at times a shallow lake, which on evaporation, may leave a deposit of salt or gypsum; playa, salt pan."

(3) The Hindu Kush

The Hindu Kush is described by Stamp (1959) as "entirely barren and uninhabited." This is only a slight exaggeration, as there are small areas of irrigated agriculture in some of the mountain valleys, and some of the mountain slopes have a sparse growth of grass that can be classified as steppe. Trees are absent except on the lower southeastern flanks of the range where there is some monsoonal rainfall. Where such rainfall is sufficient, there are coniferous forests of deodar, pine, and larch. The tree line on the Safed Koh (south of the Kabul River) has been reported at 3,300 to 3,500 m, about 1,100 to 1,200 m, below the snow line (Hermes, 1955).

4. THE TIEN SHAN AND ASSOCIATED RANGES

a. Configuration

The Tien Shan and its associated ranges (Maps 24 and 25) extend for more than 2,500 km, from just east of Samarkand eastward through the Karlik Range in the Gobi. The system trends northeast and east from the Pamir Knot and has three major spurs projecting westward into the Soviet Union. These are the Boro Horo Range (Boro Horo Uula) farthest north; a series of parallel ranges on both sides and west of the Issyk Kul terminating in the Talas Range (Talasskiy Ala-Tau); and the Alai Ranges of Trukestan between the Syr and Amu Rivers. These ranges and spurs border the major drainage basins of the Ili, Chu, and Syr rivers.

The Tien Shan is the highest mountain range north of Tibet, with crests varying between 3,000 and 6,000 m high and an average elevation of about 4,000 m. The highest peak (Pik Pobedy) is 7,444 m in elevation. In a general way, elevations decrease from west to east, as does the total area above 3,000 m. The variation in total relief is large, exceeding 5,000 m south of the crest line, although generally it is less than 3,000 m.

Though rugged, the Tien Shan complex contains many high, gently rolling plains and broad valleys with alpine meadows. These upland plains are generally above 3,000 m. Travel through the mountains is not difficult because of the broad, east-west trending intermontane valleys and the terraced or open valleys leading from the south and north to the high passes (i.e., those exceeding 4,000 m). On the lower slopes, principally on the south side of the range, are many narrow, steep-sided valleys which may be seasonally impassable due to rapid snowmelt in the highlands.

Most of the perennial drainage is on the moister, north-facing slopes. The valleys of the major rivers are long, broad, and floored with alluvial sands and gravels. Valley bottoms are between 500 and 1,000 m in elevation, except in headwater areas where they may be nearly 3,000 m high. In the lower portions of these valleys are extensive areas of marsh close to the streams; elsewhere dune fields and desert pavements flank the rivers. Terraces of widely ranging heights above the river level occur along these streams, principally in their middle courses. The downstream, uninterrupted terraces provide excellent sites for roads. In smaller valleys, particularly those not affected by mountain glaciers, the valley bottoms are narrow, rock-filled, and unterraced in both their upper and middle courses.

b. <u>Water supply</u>

North of the crest-line of the Tien Shan, particularly above 3,000 m, procurement of reliable fresh water presents no problem. The large streams are probably subject to flooding during the spring freshet. South of the divide, reliable fresh water is less abundant. Only streams discharging from glacial sources can be relied upon during late summer and fall. Many of the swamps and lakes south of the range are saline or brackish.

c. <u>Climate</u>

In the Tien Shan, the slopes bordering the Tarim Basin are extremely arid. Light summer precipitation in the eastern parts of the ranges increases westward, becomes irregularly distributed with respect to season in the inner ranges, and then changes to a spring maximum on the lower parts of the western slopes. The snowline, which is above 4,000 m in the central Tien Shan, is lower in the wetter western parts. It is located between 3,700 and 3,900 m in the Trans-Ali (Northern Pamirs), where precipitation at 3,000 m totals about 30 inches a year. Moist air striking the western and cold northern slopes of the Talas and Dzungarian Ranges (Talaskiiy and Dzungarian Ala-Tau), produces considerable snowfall, particularly during winter and early spring.

Few climatic observations above 2,000 m are available, but a two-year record at 3,400 m on the Tujuksu Glacier (between Alma Ata and the Issyk Kul) shows 30-36 inches of annual precipitation (S. Muller, 1967).

Older records from Tien Shanskaya at 3,614 m about 100 miles to the southeast, show 11 inches (Flohn, 1958). Farther west, precipitation is greater on the northern slopes of the Tien Shan, reaching 60 inches on the Talas Range (Suslov, 1961).

Alma-Ata (848 m) has 30 days with snowfall and 111 with snow cover, while nearby, Medeo Hydro Station (1,529 m) and Great Alma-Atenka See (2,511 m) have 153 and 187 days with snow cover, respectively (S. Muller, 1961). Snow cover days around Aktash (near Tashkent) total 100 to 150. Average temperatures, observed by balloon soundings in the free air above Aktash, range in July from 50°F at 3,000 m to 18°F at 5,500 m, and in January from +16°F to -13°F. Mean monthly surface temperatures near 3,500 m, at Tujuksu Glacier and Tien Shanskaya, agree with free air temperatures in July. In January, Tien Shanskaya is 20 degrees colder than both the free air and Tujuksu. This is probably too extreme a difference to be representative, since station records were for short periods. July temperatures at the Tujuksu Glacier and Tien Shanskaya are similar.

Throughout the Tien Shan it is fair to generalize that the climate is severe, with precipitation occurring predominantly in summer. In some parts the snow line extends below 4,000 m. On the northern edge of the Tarim Basin, the 2,000 m contour forms an appropriate divide between the desert below and steppe climates above. Farther north, steppe conditions occur along the borders of both the Dzungarian and the Kobdo Basins.

d. Vegetation

The predominant vegetation of the Tien Shan, above the 2,000-meter elevation, consists of meadows and scattered thickets or groves of trees. Lower elevations are comparatively dry and have a steppe vegetation, but increasing elevation brings increasing precipitation until the intermediate altitudes have good pastures and a certain amount of woody vegetation. There are, however, few forests of much extent. In some places there is a forest-steppe zone where various species of trees grow in copses (thickets). This scarcity of forests is in part a reflection of the limitations of the natural environment and partly a result of fires, over-cutting, and overgrazing of the land.

The trees that are found in the Tien Shan present a contrast, in some respects, to those of the Himalaya. There are no pines or oaks, these species being replaced in similar habitats by the wide-ranging juniper *(J. semiglobosa)*. Spruce and fir are represented in the eastern Tien Shan by the Tien Shan spruce *(Picea schrenkiana)* and Turkestan fir *(Abies semenovi)*. They do not occupy large areas any place in these mountains, but locally there are dense spruce forests between 1,850 and 2,850 m in the Kungei Range (Kungei Ala-Tau) north of the Issyk Kul, and on the northern slopes of the Terskey Range (Terskey Ala-Tau) south of the Issyk Kul at elevations between 2,100 and 2,800 m. Where these two ranges converge farther east, spruce is found between 1,800 and 2,800 m (Berg, 1950). North of the Tien Shan proper, spruce and fir both grow on the northern slopes of the Dzungarian Range between 1,500 and 2,300 m. Juniper grows at higher elevations than spruce or fir; its upper limit is about 3,000 m. South of the Dzungarian Range the forests of spruce, fir, and juniper tend to grow in open, park-like stands. They are of value both as a source of fuel and as a check on erosion.

In many of the groves and thickets of the Tien Shan, deciduous trees are more prominent than in the forests of the Himalayas. Scrub thickets of hawthorn *(Crataegus* spp.*)*, apple, and other rosaceous species are common throughout. In the extreme southwest of the region there are forests of maple *(Acer turkestanicum)* and walnut *(Juglans fallax)* up to 2,200 m, while from 2,200 to 2,700 m there are scrubby groves of maple, juniper, plum, honeysuckle, and rose (Mirov, 1951).

The zone of subalpine meadows, as distinguished from "low-mountain meadow", begins at varying altitudes. In the Fergana Range along the east flank of the Fergana Basin they appear at 2,500 to 2,700 m, and in the Alai Valley (Dolina Alayskaya) at 3,100 to 3,200 m (Berg, 1950). It is in this zone, or a little above it, that the scattered stands of spruce, fir, or juniper grow. The herbaceous vegetation of these meadows is not as tall as that of the lower mountain meadows, but it is relatively abundant.

The elevation of the tree line in the Tien Shan is given by Suslov (1961) as 3,000 to 3,500 m. Above this level are alpine meadows of sedge (chiefly cobresia), flowering plants such as edelweiss, and semi-shrubs such as saxifrage and rock jasmine, which grow among the rocks.

Hermes (1955) gives the following tree-line elevations in this region: the Kirghiz Range (Kirgizkiy Khrebet) west of the Issyk Kul, 2,800-2,900 m; the Khan Tengri Massif ESE of the Issyk Kul, 3,000 m; the Khalik Range (Khalik Tau) immediately east of the Khan Tengri, 2,800 m; and the Bogdo Range (Bogdo Uula) north of the Turfan Depression, 2700-2,800 m. The Dzungarian Range (Dzungarskiy Ala-Tau) at approximately 45° N latitude, has its tree line at 2,500 m, at least in the central part.

5. THE MONGOLIAN HIGHLANDS

a. Configuration

In this section are discussed all of the higher areas northeast of the Dzungarian Gate, a low pass which forms a natural topographic break at about 45°N. It includes the Altai Mountains, on the border between Sinkiang and Mongolia, the other uplands in Mongolia, and the Sayan Mountains of the Tuva region near the border between Mongolia and the USSR. The mountains of Mongolia exceed 3,000 m only over a comparatively small area, and they are therefore of only secondary concern in this study. For this reason, there is no detailed map of the Mongolian Highlands in this report, and the reader is referred to Map 1 for the main physiographic features.

Immediately northeast of the Dzungarian Gate rises the minor Tarbagatay Range (Sai-li Shan), with a maximum elevation slightly above 2,800 meters facing the markedly higher Altai Mountains across the Irtysh river basin.

From their highest peak, Kutiun (4,653 m), where the borders of the U.S.S.R., Sinkiang, and Mongolia meet, the Altai Mountains stretch in a slender arc for nearly 750 miles southeastward to the outlying Gobi Altai (43° N, 105° E). Several peaks exceed 4,000 meters in the western half, but summit elevations in general are lower toward the southeast and the average height of peaks throughout the system is somewhat less than 3,000 meters. There are a number of spur and satellite ranges associated with the Altai, the most prominent being the Tannu Ola which arcs east-northeastward along the Soviet-Mongolian border forming a divide between the Tuva Basin and Ubsa Nuur (lake) in the so-called Valley of the Great Lakes or Kobdo Basin.

The rocks of the Altai are for the most part crystalline and sedimentary. Typically, sandstones and conglomerates have been completely deformed and intruded by fine-grained crystalline rocks. Volcanic action has also occurred here.

The highlands which extend north and west of Kutiun, in the Soviet Union, have rounded summits which rise several hundred meters above the surrounding felsenmeer (rock slab upland). Although this upland is little dissected, travel across it would be greatly hampered by the coarse, blocky surface. Streams in this area drain mainly into the Ob River through deep, steep-sided gorges which are without terraces and difficult to ford.

The high, northwestern mountains of the Altai have been dissected by glaciers into cirques and arêtes, and much of the area is covered with permanent snow and ice fields. Near Kutiun Peak the streams head in small upland lakes or glaciers and descend into the Kobdo Basin via deep gorges. Personnel movement in this area would be difficult, and vehicular movement would not be possible except in the lower reaches of the canyons.

North of Ubsa Nuur, the Tannu-Ola Mountains rise abruptly. These mountains have broad, flat passes which average only about 1,000 m in elevation. The mountains have a hogback form with the steeper side facing south. Movement across them from the upper Yenisei Valley would be virtually unrestricted.

East of the Kobdo Basin rise the Hangai Mountains (Hangayn Nuruu). They are essentially a high, dissected plain, 1,000 to 1,500 m above the surrounding lowlands, with bald, rounded mountains rising several hundred to 1,000 m above. Streams draining southeastward and westward from these uplands flow through narrow canyons onto and across broad alluvial slopes. Many of the streams have narrow, high-level terraces and some have cut canyons as much as 90 m deep into the soft alluvial sediments. Movement in the Hangai region is almost unrestricted, but the terrain offers little concealment.

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b. Water supply

The northern portions of the Tannu-Ola Range and Hangai Mountains are drained by the Yenisei River system (Tuva Basin area). The eastern

parts of the Hangai and the Sayan Mountains drain into Lake Baikal through large, broad rivers. The western end of the Altai is drained by the Ob tributaries and the Irtysh River through Lake Zaysan. The drainage of the eastern slopes of the Altai and the western slopes of the Hangai Mountains drain to interior basins and saline lakes. Reliable fresh water sources are found in the Altai mountains and above 2,000 m in the Hangai Mountains.

c. Climate

The northwestern slopes of the Altai and the northern slopes of the western Sayans are exposed to moist air which, in spite of its distant source, produces considerable precipitation as it is lifted over the mountain slopes. Heaviest precipitation occurs below 2,000 m (Mirov, 1951). In the western Altai, about one-third of the precipitation occurs as snow, most of which remains on the mountains during the long period of low temperatures. Abundant snowfall and westerly winds produce 10-14 foot accumulations on some northern and western slopes (Suslov, 1961) but shielded basins and canyons (e.g. Kusnetsk, Minusinsk, and Tuva Basins) have little snow and a thin snow cover. Very cold nocturnal temperatures occur during calms. Warm dry föhn winds occasionally modify the climate of certain valleys and enclosed basins.

The higher parts of the Altai have snowstorms accompanied by cold winds in all seasons; even though precipitation decreases eastward, the eastern Sayans have less than a month with no snowfall. Snowlines are about 300 m lower on the northern slopes than on the southern, and are lower in the western mountains than in the east (von Wissmann, 1960). There is considerable snow on slopes at the eastern end of the Tuva Basin. More than 20 inches have been reported as persisting for three or four months at Tannu-Ola Pass. Olenya Rechka station in the Sayans has 255 days with snow cover; depths in that area reach 84 to 99 inches (Suslov, 1961).

Observations are scarce above 2,000 m in Siberia and Mongolia. They are primarily observations of glacier distribution. Extrapolation from station records below 2,000 m by use of lapse rates must be made with caution because maximum temperatures during inversions occur below 2,000 m, as does the maximum precipitation (in the north and west).

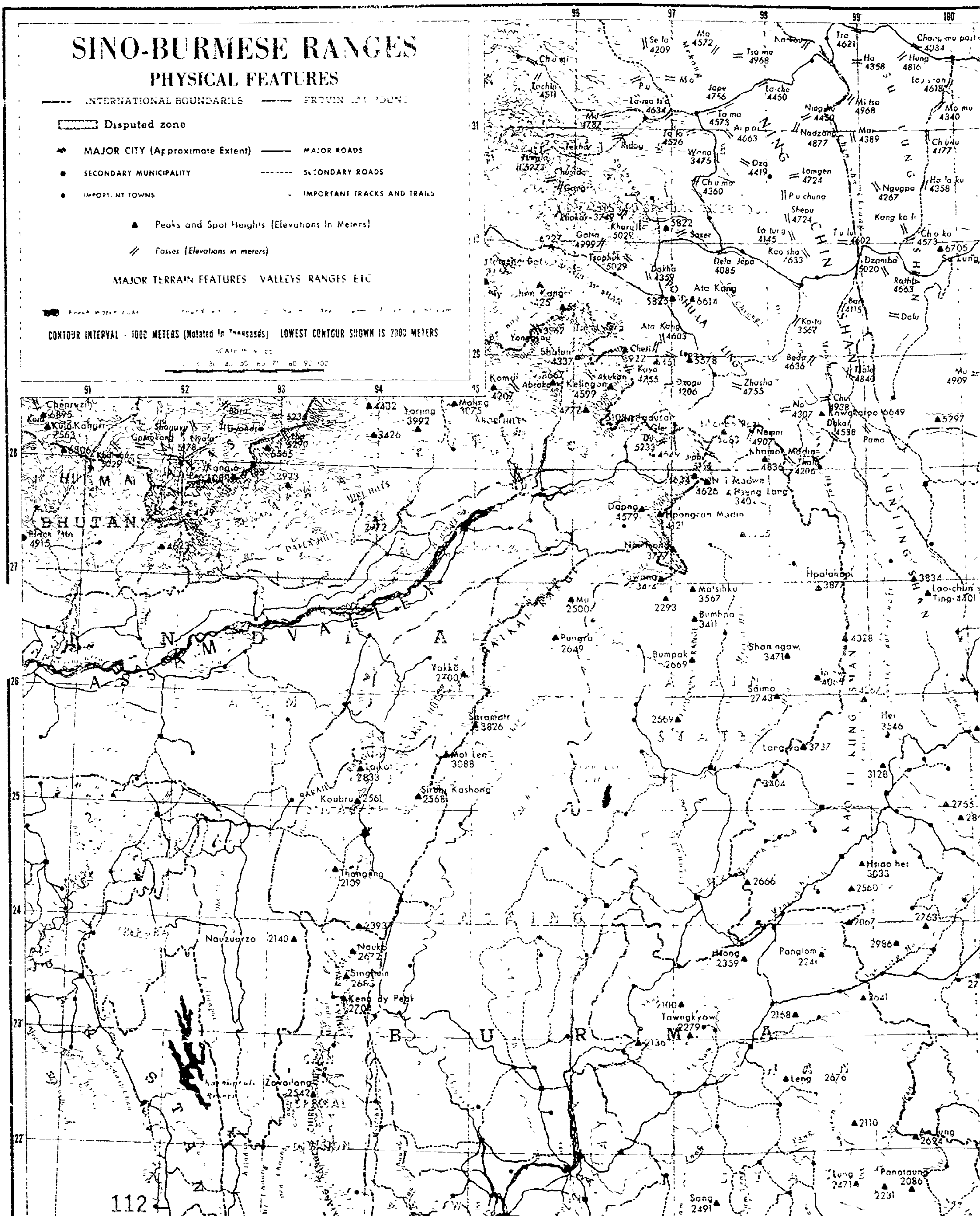
July mean temperatures average in the low 50's (F) and January mean temperatures average approximately -20°F. The mean daily temperature range is estimated to be about 20 F° with larger ranges below 2,000 m elevation, where diurnal changes of 50 F° in a day are not uncommon, and ranges of 70 F° have been reported (Murzaev, 1950). The annual extremes in this area are approximately between 100°F and -60°F.

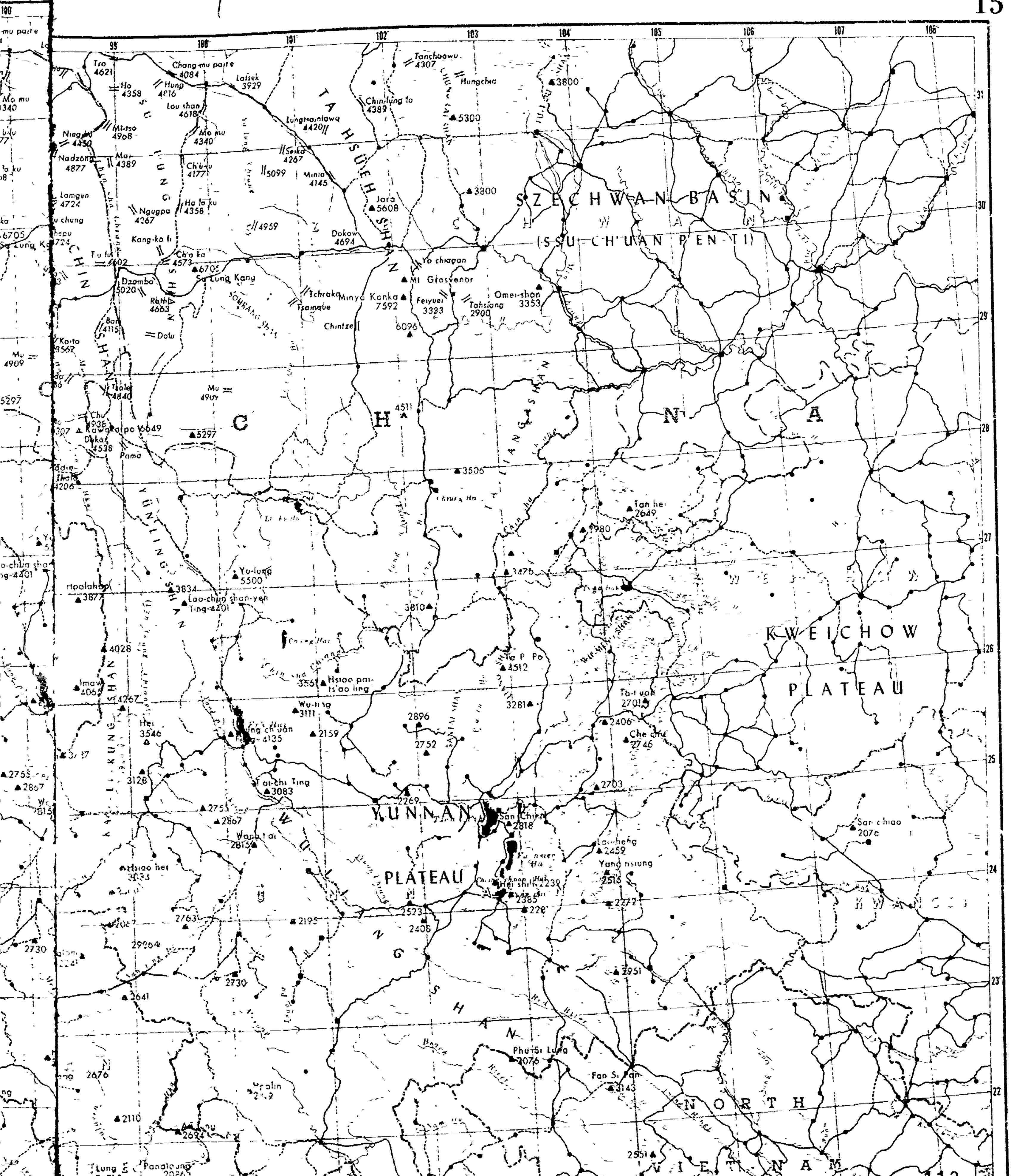
Glacier climate, with no month averaging above freezing, occurs as low as 3,000 m, although areas above 3,300 m in Siberia and Mongolia are small and few observations are available. In places, tundra climate extends down to 2,000 m. Timberline reaches above 2,000 m only in the southeastern parts of the Altai. The southeastern end of the Altai is more arid than the northwestern end and only the highest elevations have permanent snow.

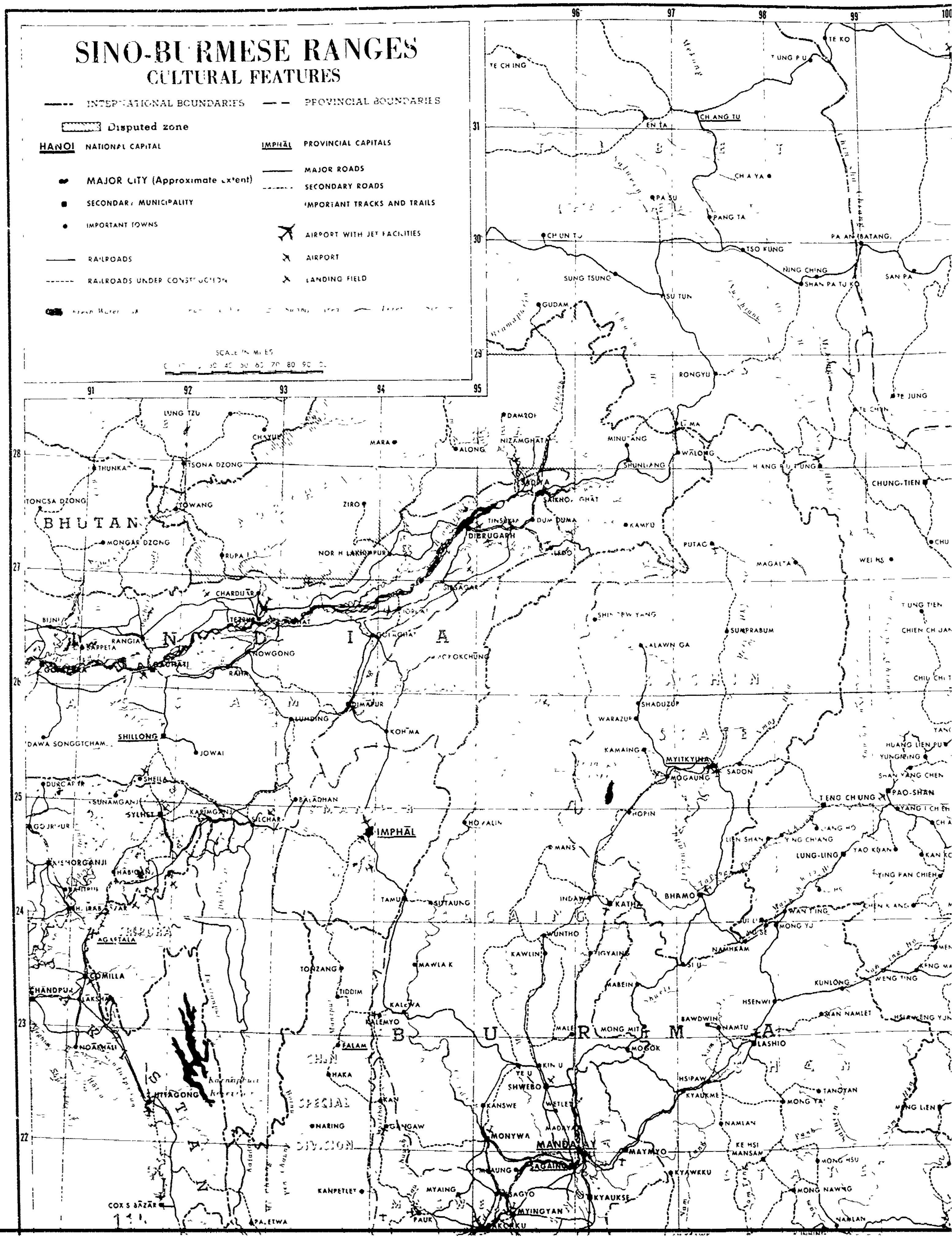
d. Vegetation

Since these mountains derive their moisture chiefly from northerly winds, the south-facing slopes tend to be drier than those with a northern exposure. As in the Tien Shan, the lower elevations have a predominantly steppe vegetation which extends above 2,000 m on some of the southern slopes. On the northern side, however, the mountain forests are an extension of the spruce-fir forests of the Siberian taiga. Some of these forests extend above 2,000 m on the northern slopes, but the characteristic vegetation above that elevation is one of coniferous thickets and subalpine meadows. The conifers here are the same species as those found in the taiga: Siberian fir *(Abies siberica)*, spruce *(Picea obovata)*, and cembra pine *(Pinus cembra)*, which is one of the white pine group although it is referred to in Russia as *kedr*. Larch, which is also a prominent component of the taiga, does not grow above 2,000 m, nor does the common or Scot's pine *(Pinus sylvestris)*, but cembra pine grows to an elevation of 2,600 m (Mirov, 1951). The subalpine meadows which occur in conjunction with the coniferous stands contain larkspur, cowparsnip, and other tall herbaceous plants.

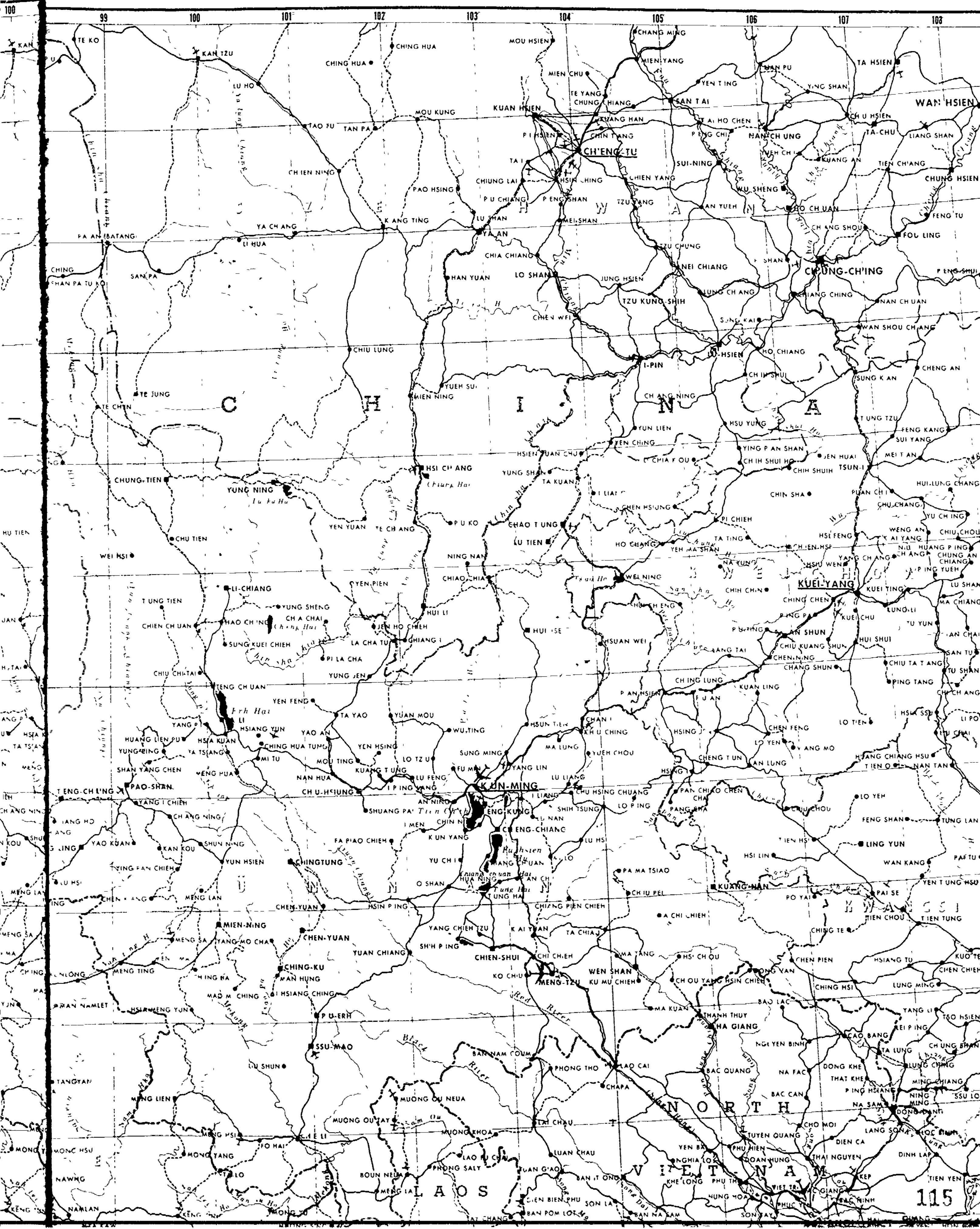
The tree line, marking the boundary between the subalpine and alpine zones, is found between 2,000 and 2,400 m. Above this elevation there are alpine meadows with a short growing period and less well developed vegetation than those below, and above 2,800-3,000 m these meadows give way to tundra similar to that of the Arctic. Above 3,300 m there are no plants except lichens.

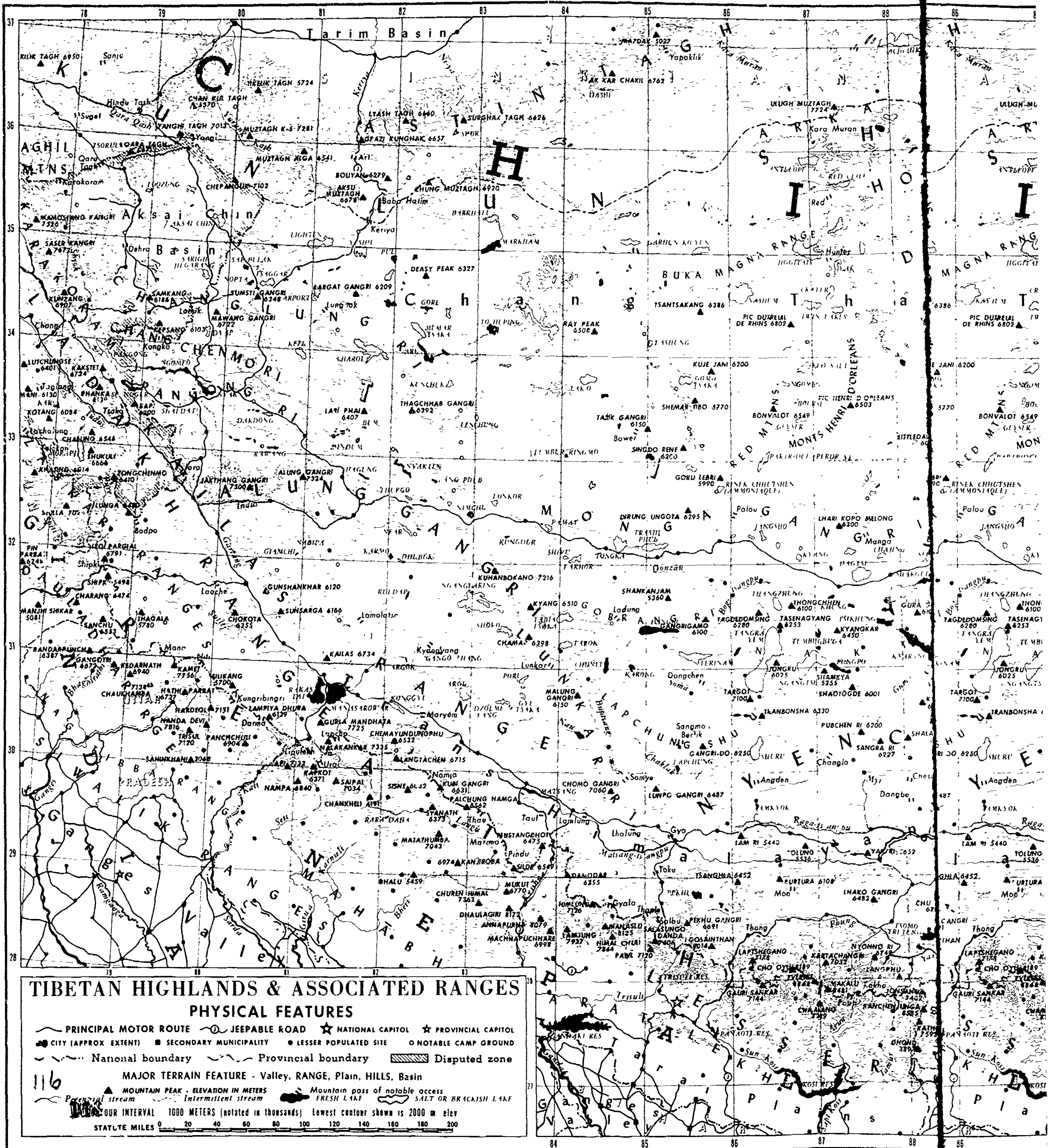

SINO-BURMESE RANGES
PHYSICAL FEATURES
Disputed zone
MAJOR CITY (Approximate Extent)
MAJOR ROADS
SECONDARY MUNICIPALITY
SECONDARY ROADS
IMPORTANT TRACKS AND TRAILS
Peaks and Spot Heights (Elevations In Meters)
Passes (Elevations in meters)
MAJOR TERRAIN FEATURES VALLEYS RANGES ETC
CONTOUR INTERVAL - 1000 METERS (Notated in Thousands) LOWEST CONTOUR SHOWN IS 2000 METERS
BHUTAN
HIMA
ASSAM
BURMA
ASSAM VALLEY
MIRI HILLS
DAFLA HILLS
PATKAI RANGE
NING CHIN
KUNG SHAN
NU SHAN


SZECHWAN BASIN
(SSU-CH'UAN PEN-TI)
KWEICHOW
PLATEAU
YUNNAN
PLATEAU
CHINA
NORTH
VIETNAM
TA HSÜEH SHAN
TA LIANG SHAN
YÜN LING SHAN
WU LIANG SHAN
HSIA KUNG SHAN
SHA LU LI SHAN
Minya Konka 7592
Mt Grosvenor
Omei-shan 3353
Feiyuei 3383
Tahsiang 2900
Tchraka
Tsanque
Chintze
Dokow 4694
Jara 5608
Chin-lung ta 4389
Tanchaowu 4307
Hungchia
Lungtsamtawa 4420
Ya chiagan
Seika 4267
Minia 4145
Yu-lung 5500
Lao-chun shan-yen Ting 4401
Hsiao pai-ts'ao ling
Wu-ting 3111
Ta P Po 4512
Tan hei 2649
Ta-t'uan 2701
Che chu 2746
San Chien 2818
Lao-heng 2459
Yang hsiung
Ta-chi Ting 3083
Wang t'ai 2815
Phu Si Lung 2076
Fan Si Pan 3143
San chiao 2076
Chang mu parte 4084
Latsek 3929
Lou shan 4618
Mo mu 4340
Ch'u-u 4177
Ha la ku 4358
Ngugpa 4267
Kang-ko li
Ch'o ka 4573
Su Lung Kang
Dzambo 5020
Rathba 4663
Dolu
Tu fu 4602
Lamgen 4724
Nadzong 4877
Niagdu 4450
Mi-tso 4968
Ho 4358
Hung 4816
Tro 4621
Mu 4909
Kawakarpo 6649
Dokar 4538
Pama
Imaw 4065
Hsiao hei 3033
Panatsung 2026
Black River
Red River

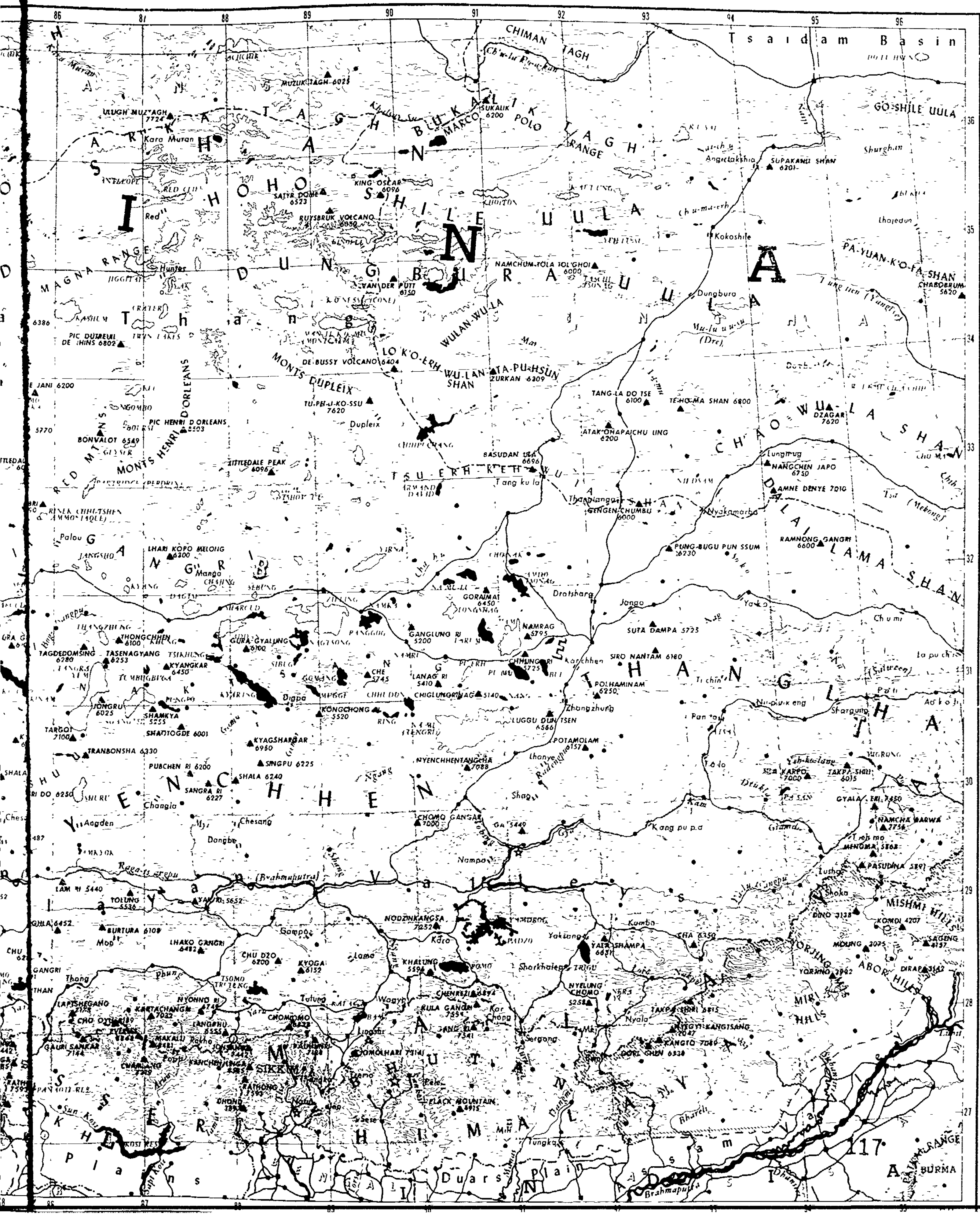


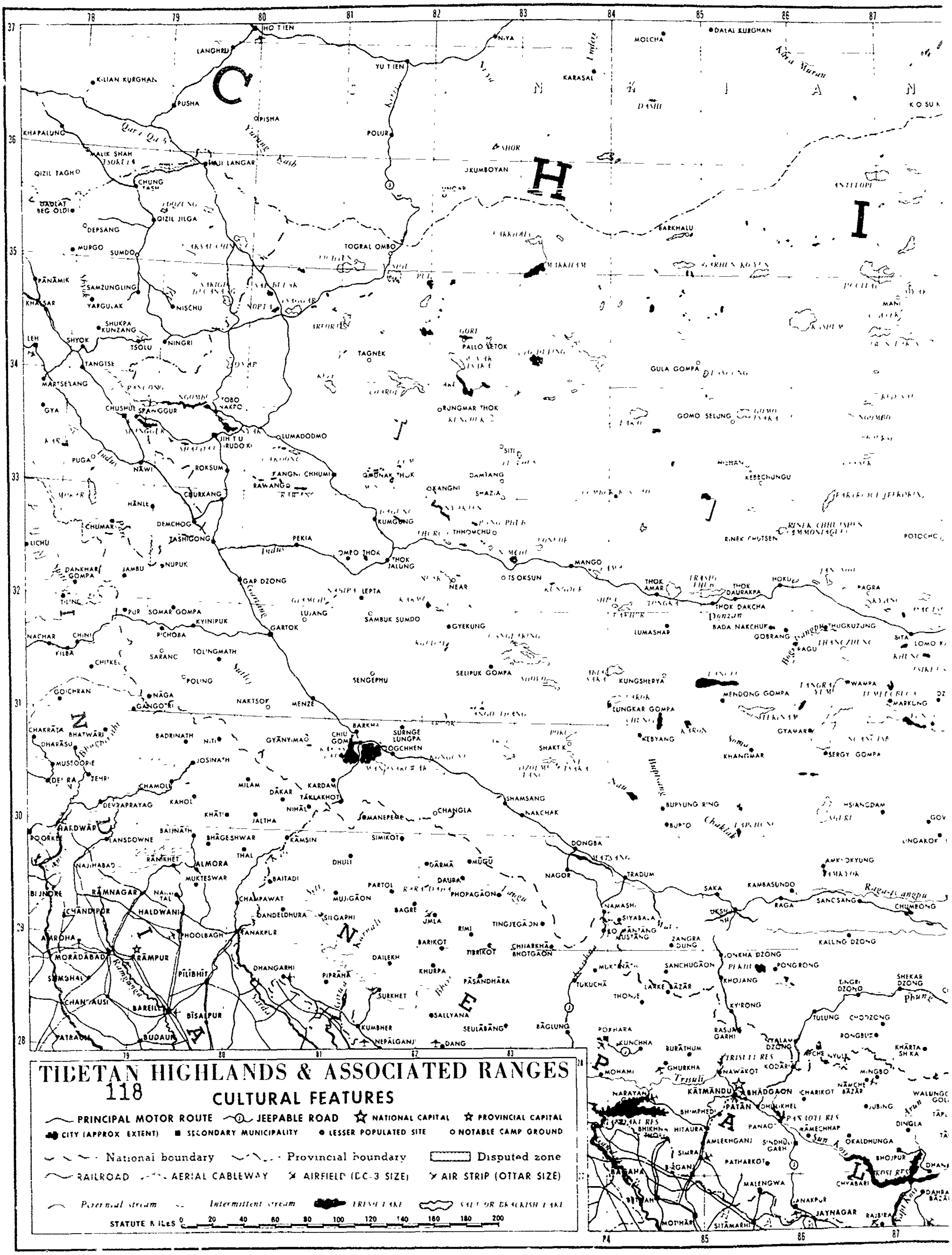
SINO-BURMESE RANGES
CULTURAL FEATURES
INTERNATIONAL BOUNDARIES
PROVINCIAL BOUNDARIES
Disputed zone
HANOI NATIONAL CAPITAL
IMPHAL PROVINCIAL CAPITALS
MAJOR ROADS
SECONDARY ROADS
IMPORTANT TRACKS AND TRAILS
MAJOR CITY (Approximate extent)
SECONDARY MUNICIPALITY
IMPORTANT TOWNS
AIRPORT WITH JET FACILITIES
RAILROADS
AIRPORT
RAILROADS UNDER CONSTRUCTION
LANDING FIELD
SCALE IN MILES
BHUTAN
INDIA
BURMA
THUNKAR
TONGSA DZONG
TSONA DZONG
TOWANG
ZIRO
MARA
ALONG
DAMROH
NIZAMGHAT
SADIYA
SAIKHOA GHAT
TINSUKIA
DUM DUMA
DIBRUGARH
NORTH LAKHIMPUR
CHARDUAR
SIBSAGAR
NOWGONG
GAUHATI
SHILLONG
JOWAI
DIMAPUR
KOHIMA
LUMDING
SYLHET
KARIMGANJ
SILCHAR
IMPHAL
TAMU
AGARTALA
COMILLA
CHANDPUR
NOAKHALI
CHITTAGONG
COX'S BAZAR
FALAM
HAKA
TIDDIM
TONZANG
KALEWA
KALEMYO
MAWLAIK
KANPETLET
MONYWA
SHWEBO
MANDALAY
SAGAING
MAYMYO
KYAUKSE
MYINGYAN
PAUK
GANGAW
MOGOK
LASHIO
HSIPAW
KYAUKME
HSENWI
KUNLONG
NAMTU
BAWDWIN
BHAMO
KATHA
INDAW
WUNTHO
MYITKYINA
MOGAUNG
SADON
HOPIN
KAMAING
WARAZUP
SHADUZUP
PUTAO
SUMPRABUM
MAGALTA
RONGYU
GUDAM
SU TUN
SUNG TSUNG
CHUN TU
EN TA
CH ANG TU
TE CHING
TUNG PU
TE KO
CH A YA
PA SU
PANG TA
TSO KUNG
NING CHING
PA AN (BATANG)
SAN PA
CHUNG-TIEN
WEI HS
TENG CHUNG
PAO-SHAN
LUNG-LING
MONG YU
NAMHKAM
WAN TING
KENG TUNG

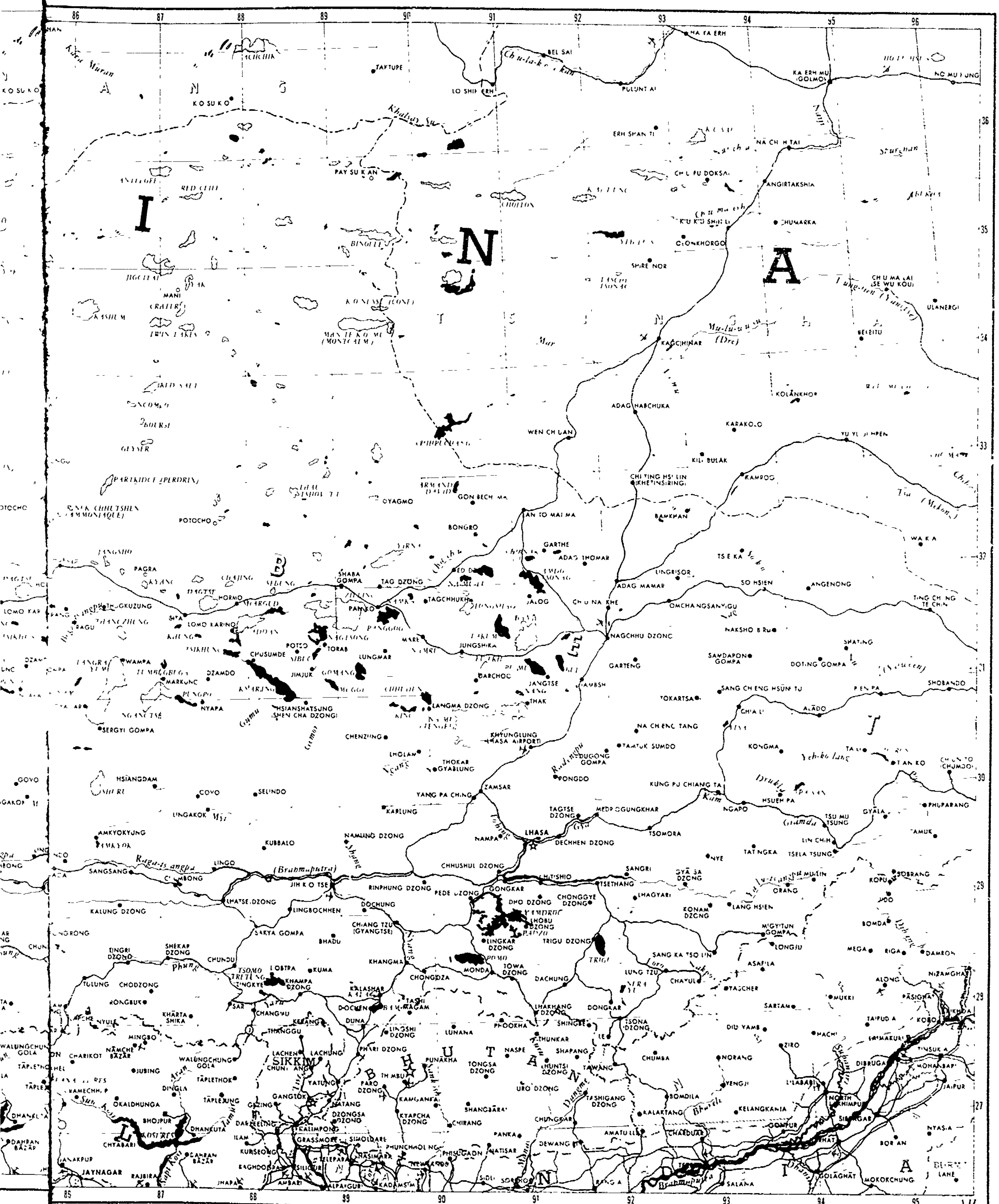

CHINA
NORTH
VIET NAM
LAOS
CH'ENG-TU
CHUNG-CH'ING
KUN-MING
KUEI-YANG
WAN HSIEN
YA AN
I-PIN
WEI NING
CHAO T UNG
LI-CHIANG
PAO-SHAN
CHING-KU
SSU-MAO
MENG-TZU
LAO CAI
HA GIANG
CAO BANG
LANG SON
THAI NGUYEN
TUYEN QUANG
LAI CHAU
PHONG SALY
WEN SHAN
AN SHUN
TSUN-I
HSI CH ANG
YUNG NING
TZU KUNG-SHIH
NEI CHIANG
SUI-NING
KUAN HSIEN
MIEN-NING
CHEN-YUAN
CHINGTUNG
PA AN (BATANG)
Red River
Black River
Mekong
115



TIBETAN HIGHLANDS & ASSOCIATED RANGES
PHYSICAL FEATURES
PRINCIPAL MOTOR ROUTE
JEEPABLE ROAD
NATIONAL CAPITOL
PROVINCIAL CAPITOL
CITY (APPROX EXTENT)
SECONDARY MUNICIPALITY
LESSER POPULATED SITE
NOTABLE CAMP GROUND
National boundary
Provincial boundary
Disputed zone
116
MAJOR TERRAIN FEATURE - Valley, RANGE, Plain, HILLS, Basin
MOUNTAIN PEAK - ELEVATION IN METERS
Mountain pass of notable access
Perennial stream
Intermittent stream
FRESH LAKE
SALT OR BRACKISH LAKE
CONTOUR INTERVAL 1000 METERS (notated in thousands) Lowest contour shown is 2000 m elev
STATUTE MILES 0 20 40 60 80 100 120 140 160 180 200
Tarim Basin
Aksai Chin
KUNLUN
Chang Tang
BUKA MAGNA RANGE
MONTS HENRI D'ORLEANS
RED MTNS
GANGRI RANGE
NYENCHEN TANGLHA
LAPCHUNG SHU
Great Himalaya
Ganges Valley
KAILAS 6734
GURLA MANDHATA 7725
NANDA DEVI 7816
DHAULAGIRI 8172
ANNAPURNA 8079
GOSAINTHAN 8014


Tsaidam Basin
CHIMAN TAGH
MUZUK TAGH 6025
ULUGH MUZTAGH 7724
Kara Muran
SUKALIK 6200
MARCO POLO RANGE
GO-SHILE UULA
SUPAKANG SHAN 6201
KING OSCAR 6096
SATYR DOME 6523
RUYSBRUK VOLCANO
HOHO SHILE UULA
Kokoshile
PA-YUAN-K'O-LA SHAN
CHABORUM 5620
MAGNA RANGE
Hunter
DUNG BURA ULA
NAMCHUM-TOLA TOL'GHOI 6000
VAN DER PUTT 6150
Dungbura
PIC DUTREUIL DE RHINS 6802
WULAN-WU-LA
LO K'O-ERH-WU-LAN-TA-PU-HSUN SHAN
DE BUSSY VOLCANO 6404
ZURKAN 6209
MONTS DUPLEIX
TU-PEI-JI-KO-SSU 7620
Dupleix
TANG-LA DO TSE 6100
TE-HO-MA SHAN 6800
DZAGAR 7620
CH'AO-WU-LA SHAN
PIC HENRI D'ORLEANS 6503
MONTS HENRI D'ORLEANS
BONVALOT 6549
ATAK OHAPAICHU LING 6200
BASUDAN ULA 6696
LITTLEDALE PEAK 6096
TSU-ERH-K'EH-WU-LA SHAN
Tang ku la
NANGCHEN JAPO 6750
AMNE DENYE 7010
GENGEN CHUMBU 6000
Nyakamarba
DALAI LAMA SHAN
LHARI KOPO MELONG 6200
PUNG-BUGU PUN SSUM 6230
RAMNONG GANGRI 6600
GORAIMAI 6450
Dratshang
GANGLUNG RI 5200
NAMRAG 5795
SUTA DAMPA 5725
THONGCHHEN 6100
GURA GYALUNG 6100
TAGDEDOMSING 6280
TASENAGYANG 6253
KYANGKAR 6450
CHE 5745
LANAG RI 5410
CHHUNGRI 5725
SIRO NANTAM 6180
THANGLHA
POLHAMINAM 6250
Zhangzhung
JONGRU 6025
SHAMKYA 5255
KONGCHONG 5520
CHIGLUNGRI 5140
LUGGU DUN TSEN 6566
TARGOT 7100
SHADTOGDE 6001
KYAGSHARGAR 6960
POTAMOLAM 6157
TRANBONSHA 6330
PUBCHEN RI 6200
SINGPU 6225
NYENCHHENTANGLHA 7088
SHALA 6240
SANGRA RI 6227
NYENCHHEN THANGLHA
Changlo
Chesang
CHOMO GANGAR 7000
GA 5449
Kang pu p'a
Dongbe
Nampa
Raga tsangpo
(Brahmaputra)
Valleys
LAM RI 5440
TOLUNG 5536
BURTURA 6105
LHAKO GANGRI 6482
NODZINKANGSA 7252
YAMDROK
YALA SHAMPA 6631
CHU DZO 6200
KYOGA 6152
KHALUNG 5596
Gampo
Lamo
Kamba
Yaksang
Shorkhalep
NYONNO RI 6745
KARTACHANGRI 7022
LAPTSHEGANG 7175
CHO OYU 8189
EVEREST 8848
MAKALU 8481
GAURI SANKAR 7154
CHOMOMO 6838
KULA GANGRI 7554
NYELUNG CHOMO 5254
TAKPA SHIRI 5815
NYENCHHEN KANGTSANG 7047
KANGTO 7089
GORI CHEN 6538
KANCHENJUNGA 8585
SIKKIM
BHUTAN
CHOMOLHARI 7314
BLACK MOUNTAIN 4915
KOSI
Plains
Duars Plain
Brahmaputra
Assam
MIRI HILLS
ABOR HILLS
MISHMI HILLS
NAMCHA BARWA 7756
GYALA PERI 7150
PASUDINA 5891
DIRAP 3642
PATKAI RANGE
BURMA
HIMALAYA
117


TIBETAN HIGHLANDS & ASSOCIATED RANGES
118
CULTURAL FEATURES
PRINCIPAL MOTOR ROUTE
JEEPABLE ROAD
NATIONAL CAPITAL
PROVINCIAL CAPITAL
CITY (APPROX EXTENT)
SECONDARY MUNICIPALITY
LESSER POPULATED SITE
NOTABLE CAMP GROUND
National boundary
Provincial boundary
Disputed zone
RAILROAD
AERIAL CABLEWAY
AIRFIELD (DC-3 SIZE)
AIR STRIP (OTTAR SIZE)
Perennial stream
Intermittent stream
STATUTE MILES 0 20 40 60 80 100 120 140 160 180 200


86
87
88
89
90
91
92
93
94
95
96
NA FA ERH
BEL SAI
TAKTUPE
KO SU KO
LO SHIH ERH
PULUNT AI
KA ERH MU (GOLMO)
NC MU HUNG
Khalun Su
ERH SHAN TI
NA CH H TAI
PAY SU K AN
CHU FU DOKSA
ANGIRTAKSHIA
CHUMARKA
CHONKHORGO
SHIRE NOR
CH U MA LAI (SE WU KOU)
ULANERGI
MANI
CRATER
TWIN LAKES
KAGCHINAR
Mu-lu-u-su
(Dre)
ADAG NABCHUKA
KOLANKHO
KARAKOLO
WEN CH UAN
YU YI JI HPEN
KILI BULAK
KAMDOG
CHI TING HSI LIN (KHETINSIRING)
GON BECH MA
OYAGMO
POTOCHO
AN TO MAI MA
BONGRO
GARTHE
ADAG THOMAR
TSE KA
LINGRISOR
ADAG MAMAR
SO HSIEN
ANGENONG
PAGRA
SHABA GOMPA
TAG DZONG
TAGCHHUKHA
CHU NA KHE
OMCHA NGSAN GU
LOMO KARING
NAGCHHU DZONG
NAKSHO B RU
SHATING
JALOG
CHUSUMDE
TORAB
LUNGMAR
JUNGSHIKA
MARE
GARTENG
SAMDAPON GOMPA
DOTING GOMPA
DZAMDO
MARKUNC
JIMJUK
BARCHOC
JANGTSE
TAMBSH
TOKARTSA
SANG CH ENG HSUN TU
SHOBANDO
NYAPA
LANGMA DZONG
THAK
HSIANSHATSUNG (SHEN CHA DZONG)
SERGYI GOMPA
CHENZUNG
NA CH ENG TANG
KONGMA
KHYUNGLUNG (LHASA AIRPORT)
TAMTUK SUMDO
DUGONG GOMPA
THOKAR
GYABLUNG
TAN KO
PONGDO
HSIANGDAM
GOVO
COVO
SELINDO
KUNG PU CHIANG TA
ZAMSAR
YANG PA CHING
KARLUNG
HSUEH PA
NGAPO
GYALA
PHUPARANG
TAGTSE DZONG
MEDRO GUNGKHAR
TSU MU TSUNG
UNGAKOK
AMKYOKYUNG
NAMLING DZONG
KUBBALO
NAMPA
LHASA
DECHHEN DZONG
TSOMORA
LIN CHIH
TAMUK
TAT NGKA
TSELA TSUNG
NYE
SANGSANG
LINGO
(Brahmaputra)
CHHUSHUL DZONG
SANGRI
GYA SA DZONG
SOBRANG
KOPU
JIH K O TSE
RINPHUNG DZONG
PEDE DZONG
GONGKAR
TSETHANG
LHAGYARI
ORANG
LANG HSIEN
KHATSE DZONG
LINGBOCHHEN
DOCHUNG
DHO DZONG
CHONGGYE DZONG
KONAM DZONG
KALUNG DZONG
CHIANG TZU (GYANGTSE)
LINGKAR DZONG
TRIGU DZONG
BOMDA
SAKYA GOMPA
BHADU
TINGRI DZONG
SHEKAR DZONG
CHUNDU
KHANGMA
TOWA DZONG
MONDA
SANG KA TSO LIN
LONGJU
MEGA
RIGA
DAMRON
TSOMO TRETUNG
TINGKYE
KHAMPA DZONG
KUMA
CHONGDZA
DACHUNG
LUNG TZU
CHAYUL
ASAFILA
NIZAMGHAT
TULUNG
CHODZONG
KALASHAR
TASHI
YAGCHER
ALONG
RONGBUK
KHARTA SHIKA
SAR
CHANGMU
DOCHEN
LHAKHANG DZONG
DONGKAR
SARTAM
MUKKI
PASIGHAT
DUNA
PHARI DZONG
LINGSHI DZONG
PHOOKHA
SHINGBE
TSONA DZONG
DIU YAME
TAIPUD A
KOBO
MINGBO
THANGGU
LUNANA
THUNKAR
HACHI
NAMCHE BAZAR
CHARIKOT
WALUNGCHUNG GOLA
LACHEN
LACHUNG
PUNAKHA
TONGSA DZONG
NASPE
SHAPANG
TAWANG
CHUMBA
NORANG
ZIRO
SIKKIM
BHUTAN
JUBING
TAPLETHOK
YATUNG
PARO DZONG
URO DZONG
YENGJI
DIBRUGARH
OKALDHUNGA
DINGLA
TAPLEJUNG
GANGTOK
KANGANKA
TASHIGANG DZONG
BOMDILA
NORTH LAKHIMPUR
SHANGBARA
KELANGKANIA
BHOJPUR
DHANKUTA
DZONGSA DZONG
KYAPCHA DZONG
CHIRANG
KALAKTANG
DARJEELING
KALIMPONG
CHUNGKAR
GOHPUR
SIBSAGAR
CHYABARI
ILAM
GRASSMORE
SIMOLBARE
AMATULLA
CHARDUAR
NYASIA
KURSEONG
PHUNCHHOL NG
PANKA
DEWANG
JORHAT
BOR AN
JAYNAGAR
RAJBIRAJ
DAHRAN BAZAR
SILIGURI
NEWAKROO
TELEPARA
PHISUGAON
MATISAR
SALANA
GOLAGHAT
MOKOKCHUNG
JHAPA
AMBARI
JALPAIGURI
SIDLI
RENGA
Brahmaputra
85
87
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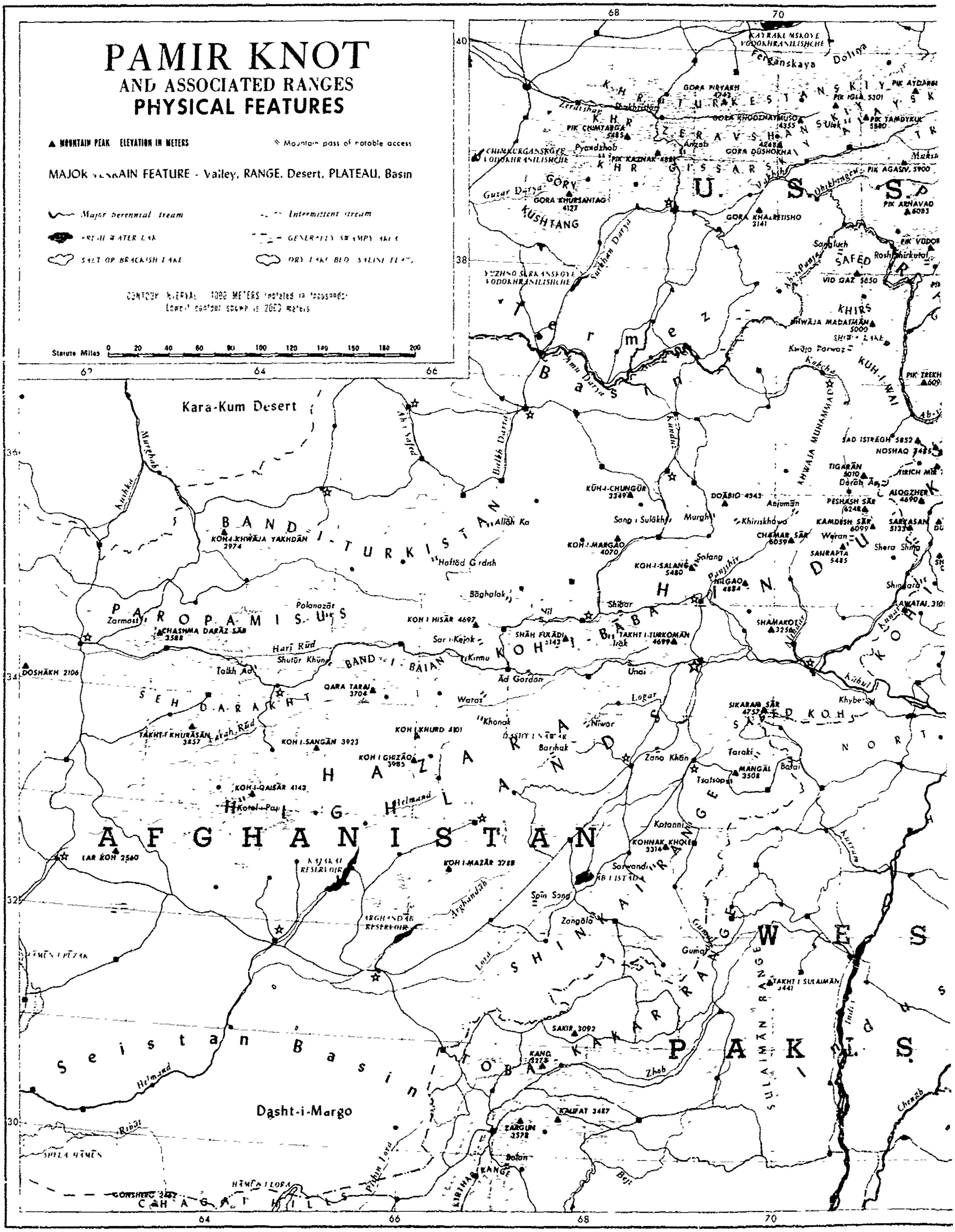
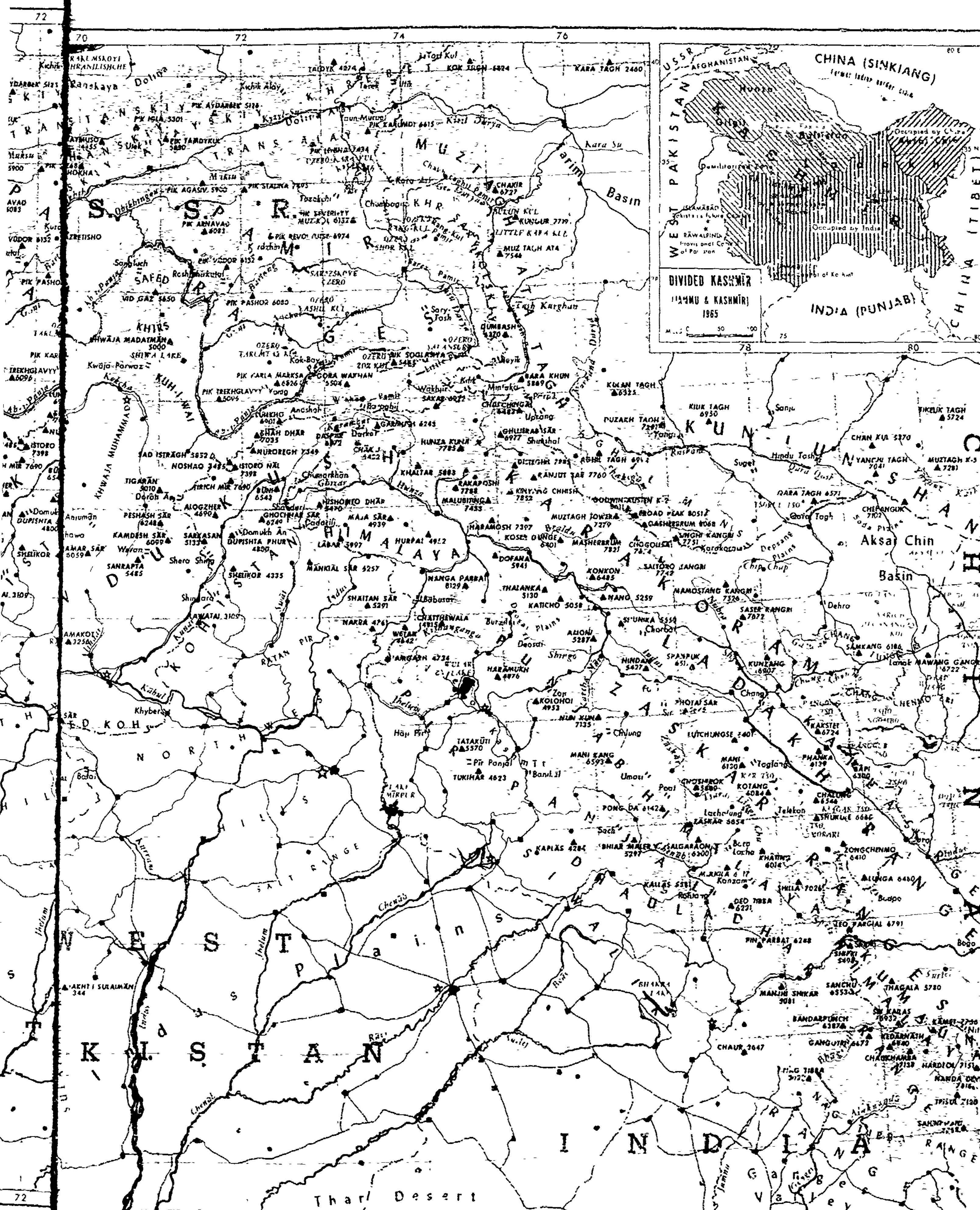
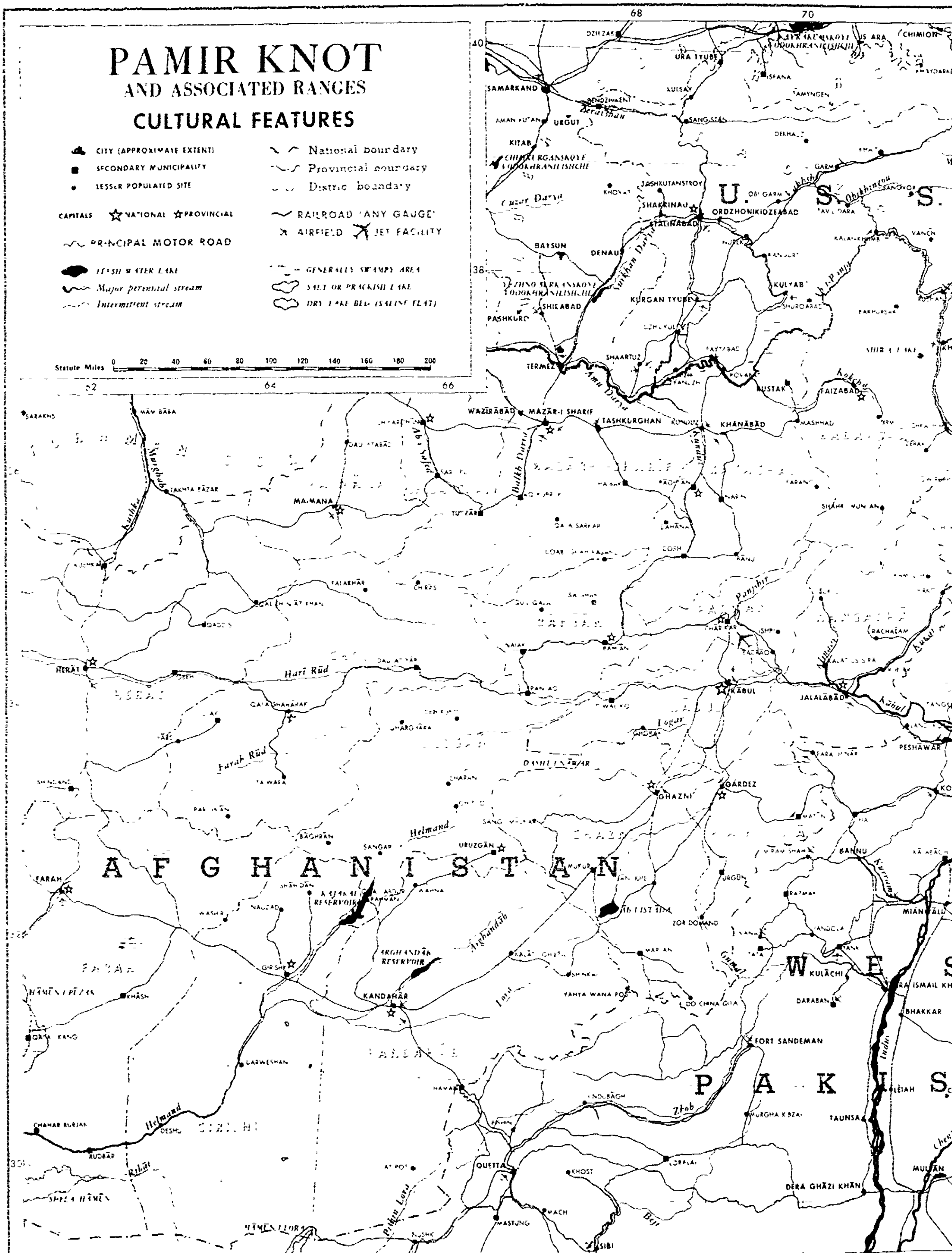
31
30
29
28
27


PAMIR KNOT
AND ASSOCIATED RANGES
PHYSICAL FEATURES
MOUNTAIN PEAK ELEVATION IN METERS
Mountain pass of notable access
Major perennial stream
Intermittent stream
FRESH WATER LAKE
GENERALLY SWAMPY AREA
SALT OR BRACKISH LAKE
DRY LAKE BED SALINE FLAT
Statute Miles
0
20
40
60
80
100
120
140
160
180
200
Kara-Kum Desert
BAND-I-TURKISTAN
PAROPAMISUS
KOH-I-BABA
HINDU KUSH
HAZARA HIGHLAND
AFGHANISTAN
Seistan Basin
Dasht-i-Margo
SULAIMAN RANGE
TOBA KAKAR RANGE
SHINKAI RANGE
PAKISTAN
Termez Basin
Hari Rud
Helmand
Amu Darya
Kabul
Indus
DOSHAKH 2106
KOH-I-KHWAJA YAKHDAN 2974
CHASHMA DARAZ SAR 3588
QARA TARAI 3704
TAKHT-I KHURASAN 3857
KOH-I-SANGAN 3923
KOH-I GHIZAO 3985
KOH-I-QAISAR 4143
KOH-I-MAZAR 3788
KOH-I-SALANG 5480
SAKIR 3092
KALIFAT 3487
ZARGUN 3578
TAKHT-I SULAIMAN 3441
TAKHT-I-TURKOMAN 4699
SIKARAM SAR 4757
MANGAL 3508
KOHNAK KHOLE 3314
KOH-I-CHUNGUR 3349
KOH-I-MARGAO 4070
SHAMAKOT 3256
GORA KHURSANTAG 4127
PIK CHIMTARGA 5485
KUSHTANG
Ferganskaya Dolina
Zeravshan
Surkhan Darya
Balkh Darya
Murghab
Kushka
Ab-i-Safed
Arghandab
Lora
Zhob
Gumal
Kurram
Chenab
Kandahar
KAJAKAI RESERVOIR
ARGHANDAB RESERVOIR
AB-I ISTADA
CHAGAI HILLS
62
64
66
68
70
40
38
36
34
32
30


DIVIDED KASHMIR
(JAMMU & KASHMIR)
1965
CHINA (SINKIANG)
USSR
AFGHANISTAN
WEST PAKISTAN
INDIA (PUNJAB)
CHINA (TIBET)
Occupied by India
Demilitarized Zone
Hunza
Gilgit
Baltistan
ISLAMABAD
RAWALPINDI
TRANS ALAY
PAMIR
MUZTAGH ATA
Basin
Kara Su
HINDU KUSH
HIMALAYA
KARAKORAM
KUNLUN SHAN
Aksai Chin
Basin
LADAKH
ZASKAR
PIR PANJAL
SIWALIK
SALT RANGE
NANGA PARBAT 8129
RAKAPOSHI 7788
HARAMOSH 7397
MASHERBRUM 7821
BROAD PEAK 8051
GASHERBRUM 8068
NUN KUN 7135
KAMET 7756
NANDA DEVI 7816
Chang Chenmo
Deosai Plains
NORTH WEST
Hajji Pir
Pir Panjal
Khyber
Kabul
Jhelum
Chenab
Ravi
Sutlej
Beas
Indus
WEST PAKISTAN
PAKISTAN
INDIA
Thar Desert
Ganges Valley
70
72
74
76
78
80


PAMIR KNOT
AND ASSOCIATED RANGES
CULTURAL FEATURES
CITY (APPROXIMATE EXTENT)
SECONDARY MUNICIPALITY
LESSER POPULATED SITE
CAPITALS NATIONAL PROVINCIAL
PRINCIPAL MOTOR ROAD
FRESH WATER LAKE
Major perennial stream
Intermittent stream
National boundary
Provincial boundary
District boundary
RAILROAD (ANY GAUGE)
AIRFIELD JET FACILITY
GENERALLY SWAMPY AREA
SALT OR BRACKISH LAKE
DRY LAKE BED (SALINE FLAT)
Statute Miles
0
20
40
60
80
100
120
140
160
180
200
U. S. S.
AFGHANISTAN
W E S
P A K I S
SAMARKAND
URA TYUBE
STALINABAD
ORDZHONIKIDZEABAD
KULYAB
KURGAN TYUBE
TERMEZ
BAYSUN
DENAU
SHIRABAD
PASHKURD
MAZAR-I SHARIF
TASHKURGHAN
KHANABAD
FAIZABAD
MAIMANA
HERAT
Hari Rud
KABUL
JALALABAD
PESHAWAR
GHAZNI
GARDEZ
BANNU
Helmand
Farah Rud
FARAH
KANDAHAR
ARGHANDAB RESERVOIR
FORT SANDEMAN
QUETTA
MASTUNG
SIBI
KHOST
DERA GHAZI KHAN
MULTAN
TAUNSA
BHAKKAR
KULACHI
DARABAN
URUZGAN
SANGAR
CHAHAR BURJAK
RUDBAR
Amu Darya
Panjshir
Logar
Kabul
Zhob
Indus
Gumal
Kurram
Murghab
Kushka
Balkh Darya
Kokcha
Lora
Rabat
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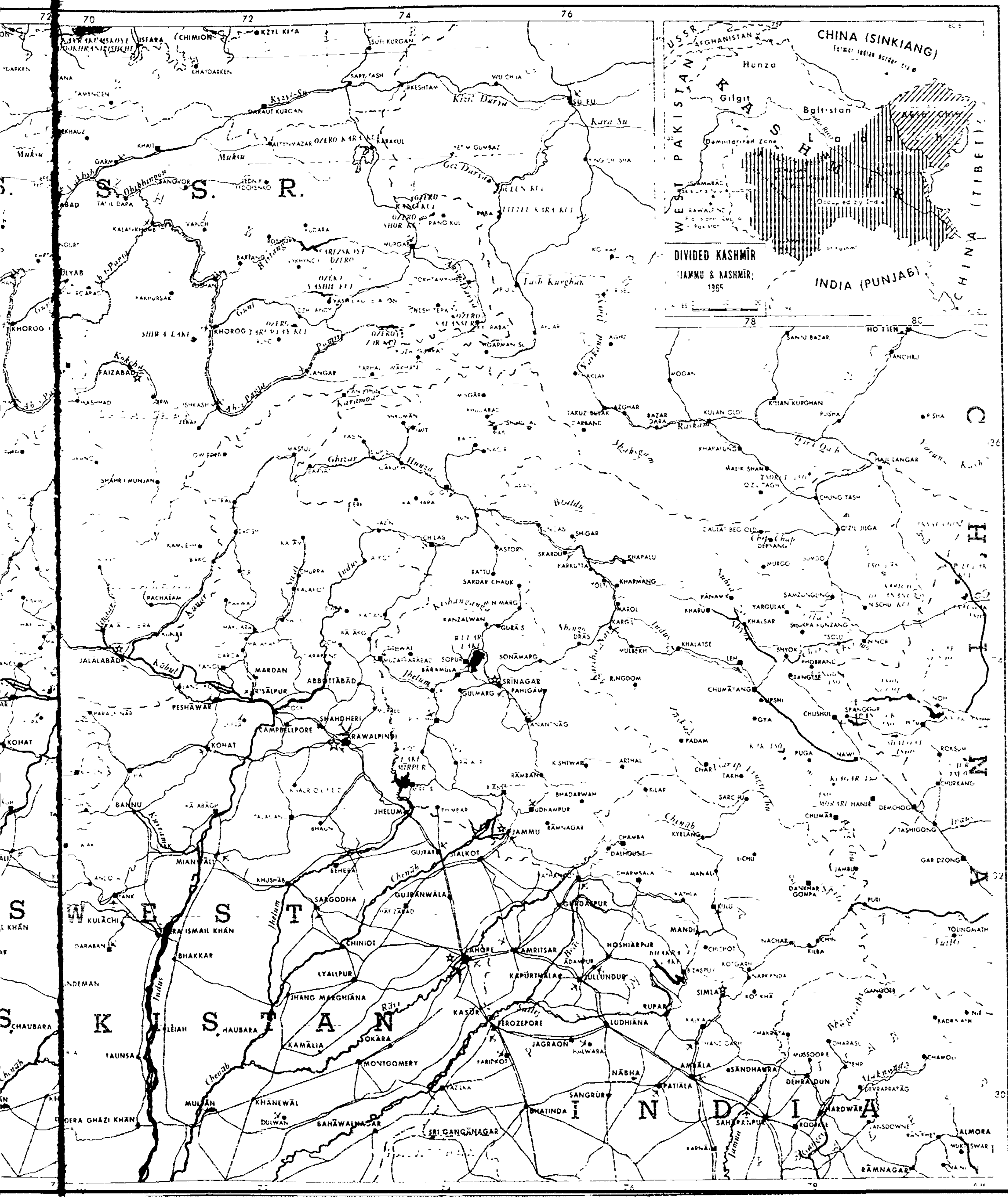
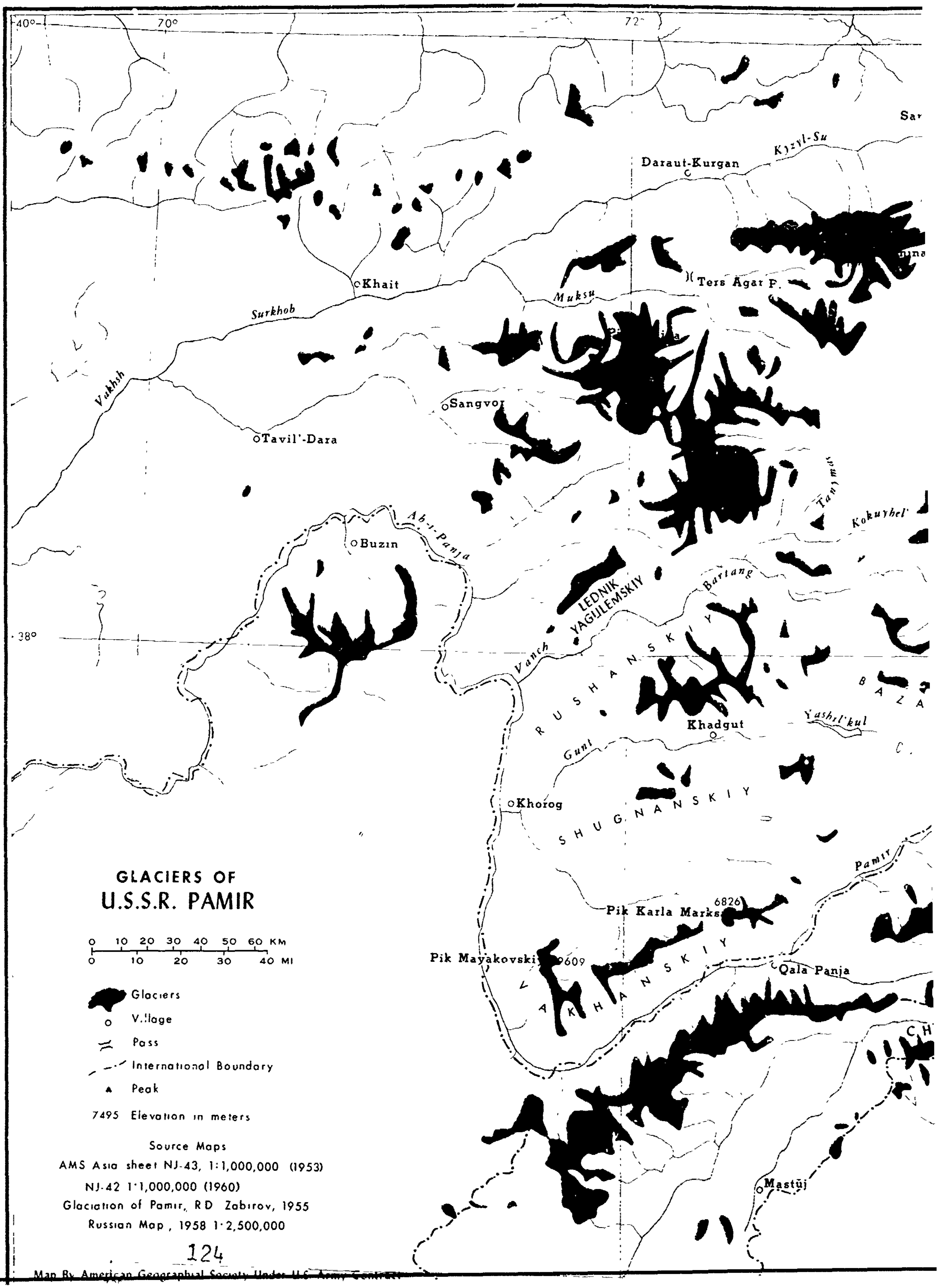
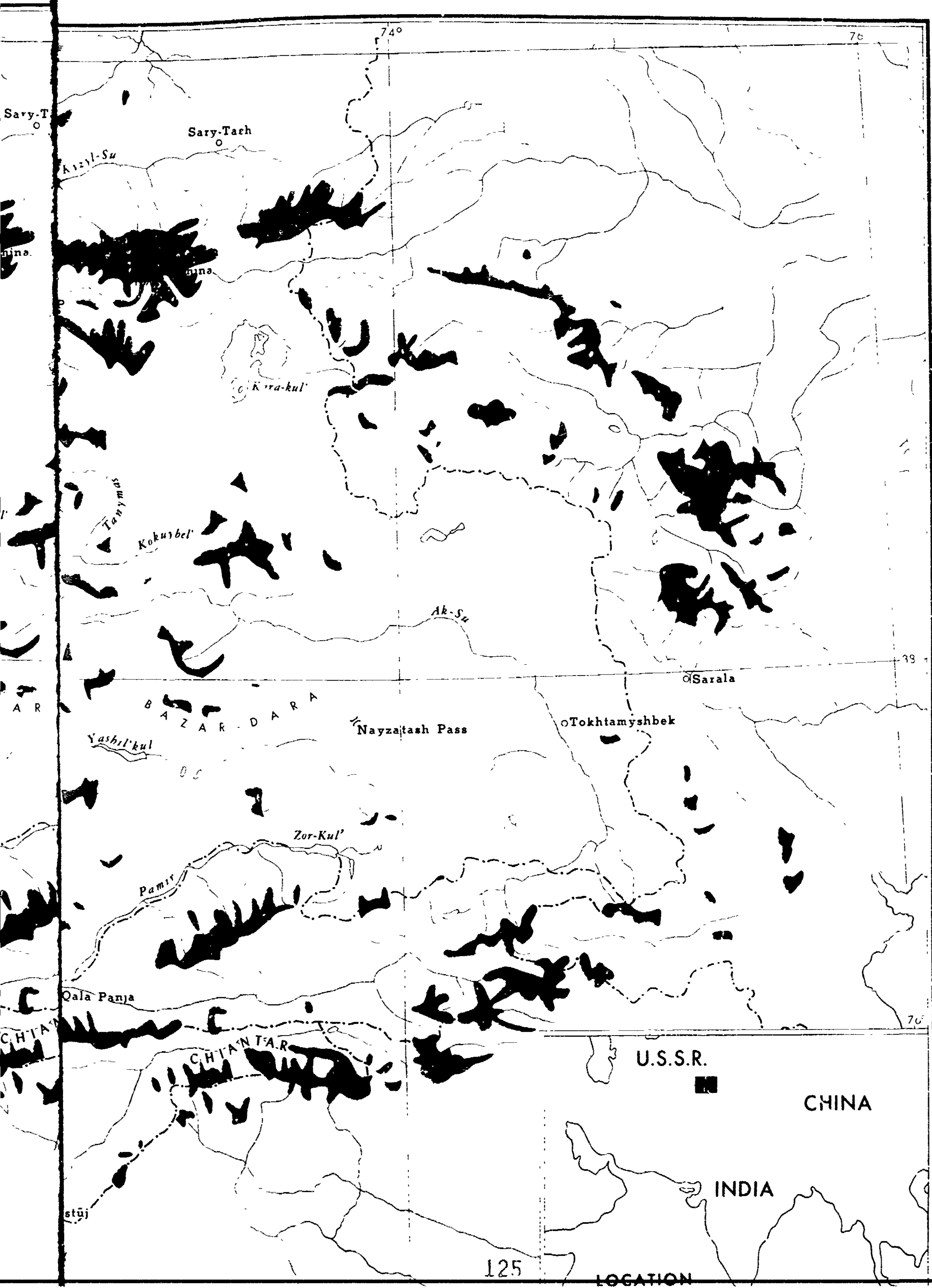
64
66
62
40
38

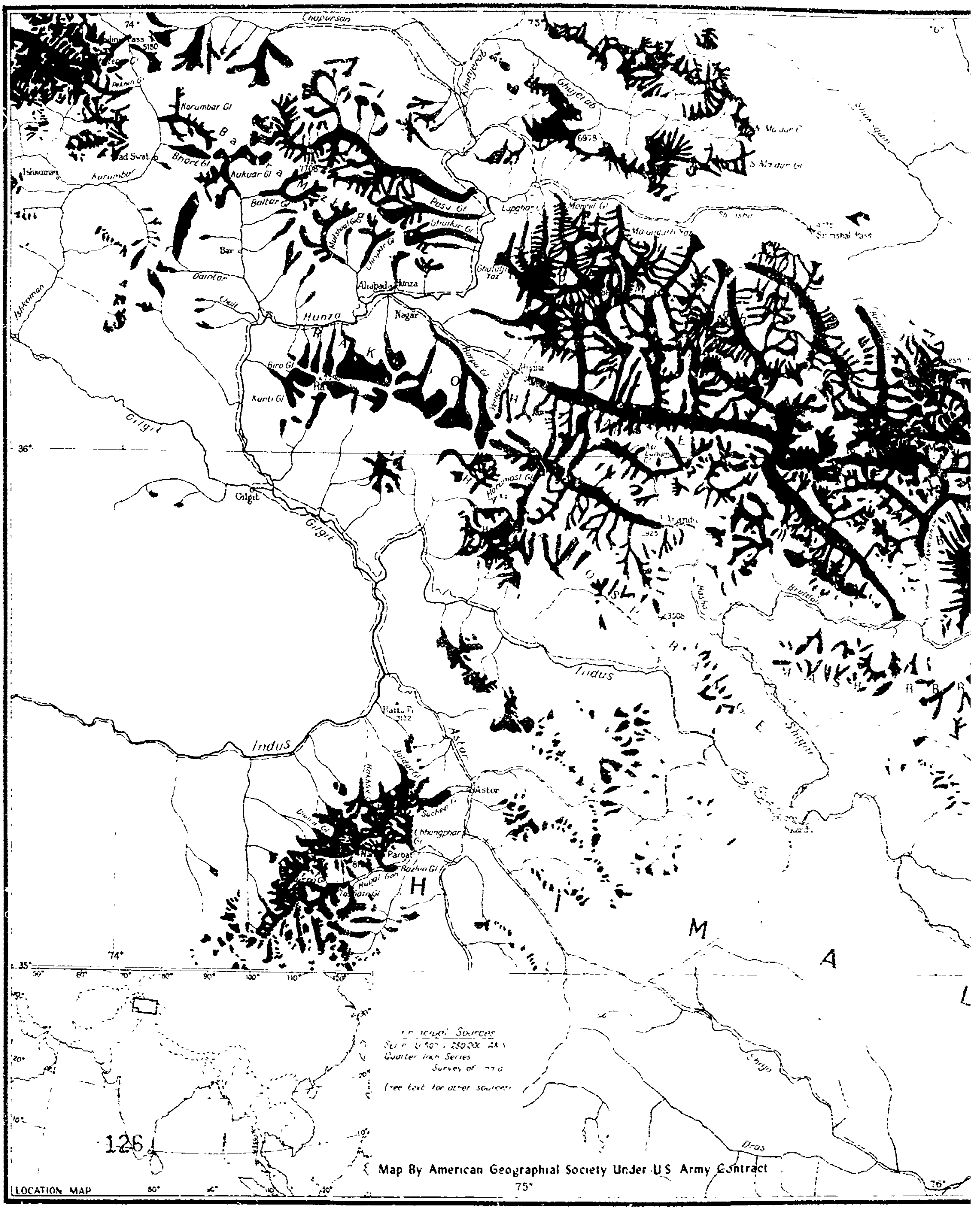


DIVIDED KASHMIR
(JAMMU & KASHMIR)
1965
CHINA (SINKIANG)
INDIA (PUNJAB)
WEST PAKISTAN
Hunza
Gilgit
Baltistan
Demilitarized Zone
Occupied by India
S. S. R.
W E S T
K I S T A N
I N D I A
C H I N A
SAPY TASH
DARAUT KURGAN
Kara Su
Muksu
Gez Darya
Tash Kurghan
FAIZABAD
Kokcha
ISHKASHIM
LANGAR
KHOROG
Hunza
Ghizar
Shaksgam
Indus
Kishanganga
Jhelum
Chenab
Kabul
Kunar
Swat
Ravi
Sutlej
Beas
CHILAS
ASTOR
SKARDU
SHIGAR
KHAPALU
PARKUTTA
KARGIL
DRAS
LEH
KHALATSE
CHUMATANG
CHUSHUL
DEMCHOK
JALALABAD
PESHAWAR
MARDAN
ABBOTTABAD
MUZAFFARABAD
BARAMULA
SOPUR
SRINAGAR
GULMARG
SONAMARG
PAHLGAM
ANANTNAG
KISHTWAR
RAMBAN
UDHAMPUR
JAMMU
KOHAT
CAMPBELLPORE
RAWALPINDI
MIRPUR
JHELUM
BANNU
MIANWALI
GUJRAT
SIALKOT
GUJRANWALA
SARGODHA
CHINIOT
LYALLPUR
JHANG MAGHIANA
LAHORE
AMRITSAR
KAPURTHALA
JULLUNDUR
HOSHIARPUR
GURDASPUR
DALHOUSIE
CHAMBA
DHARMSALA
MANDI
SIMLA
KASUR
FEROZEPORE
LUDHIANA
RUPAR
KAMALIA
OKARA
MONTGOMERY
FARIDKOT
JAGRAON
NABHA
PATIALA
AMBALA
SANGRUR
BHATINDA
MULTAN
KHANEWAL
BAHAWALNAGAR
SRI GANGANAGAR
DERA GHAZI KHAN
DERA ISMAIL KHAN
BHAKKAR
LEIAH
TAUNSA
SAHARANPUR
ROORKEE
DEHRA DUN
MUSSOORIE
HARDWAR
LANSDOWNE
ALMORA
RAMNAGAR
HO TIEN
HAJI LANGAR
DAULAT BEG OLDI
70
72
74
76
78
80

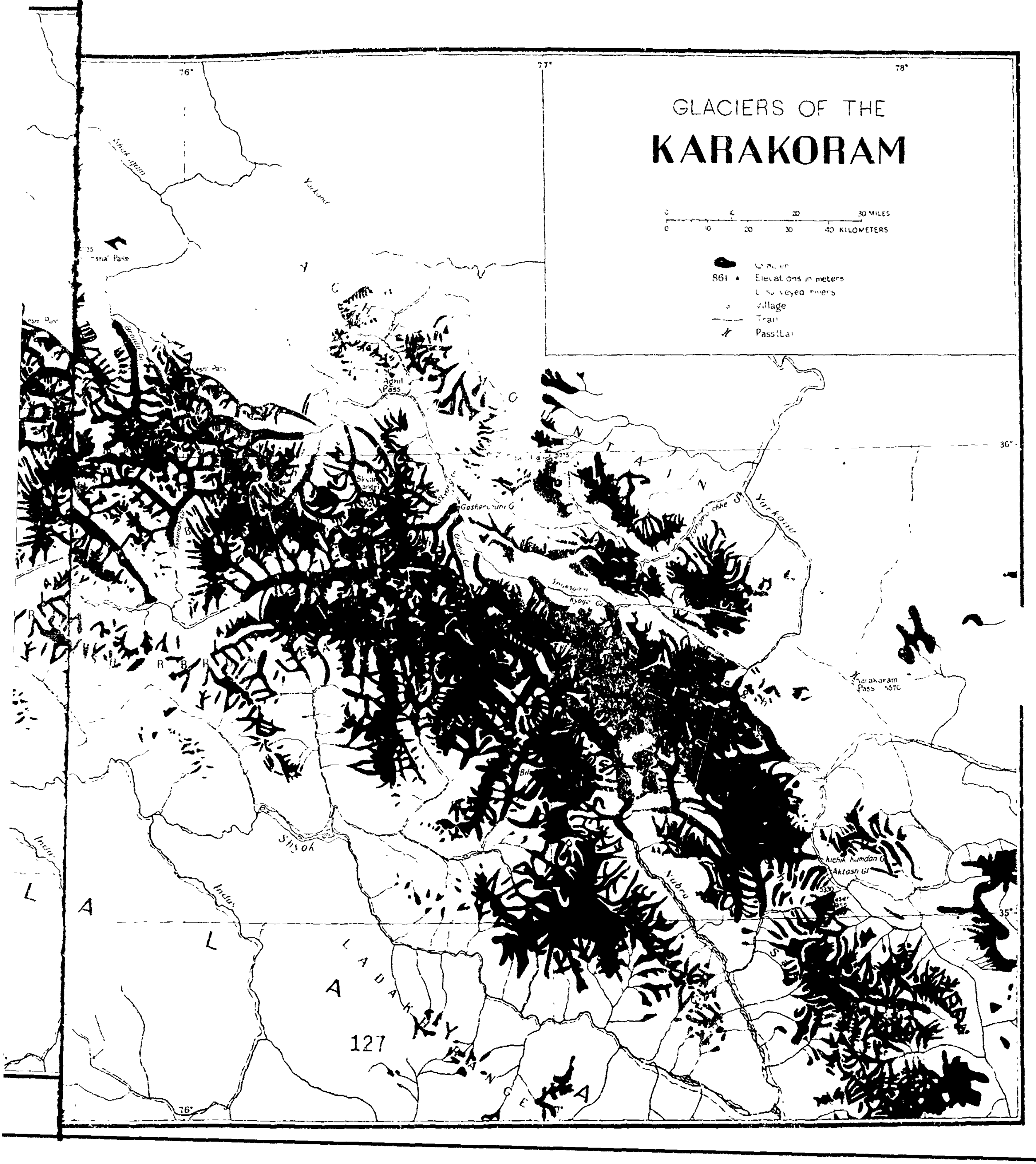


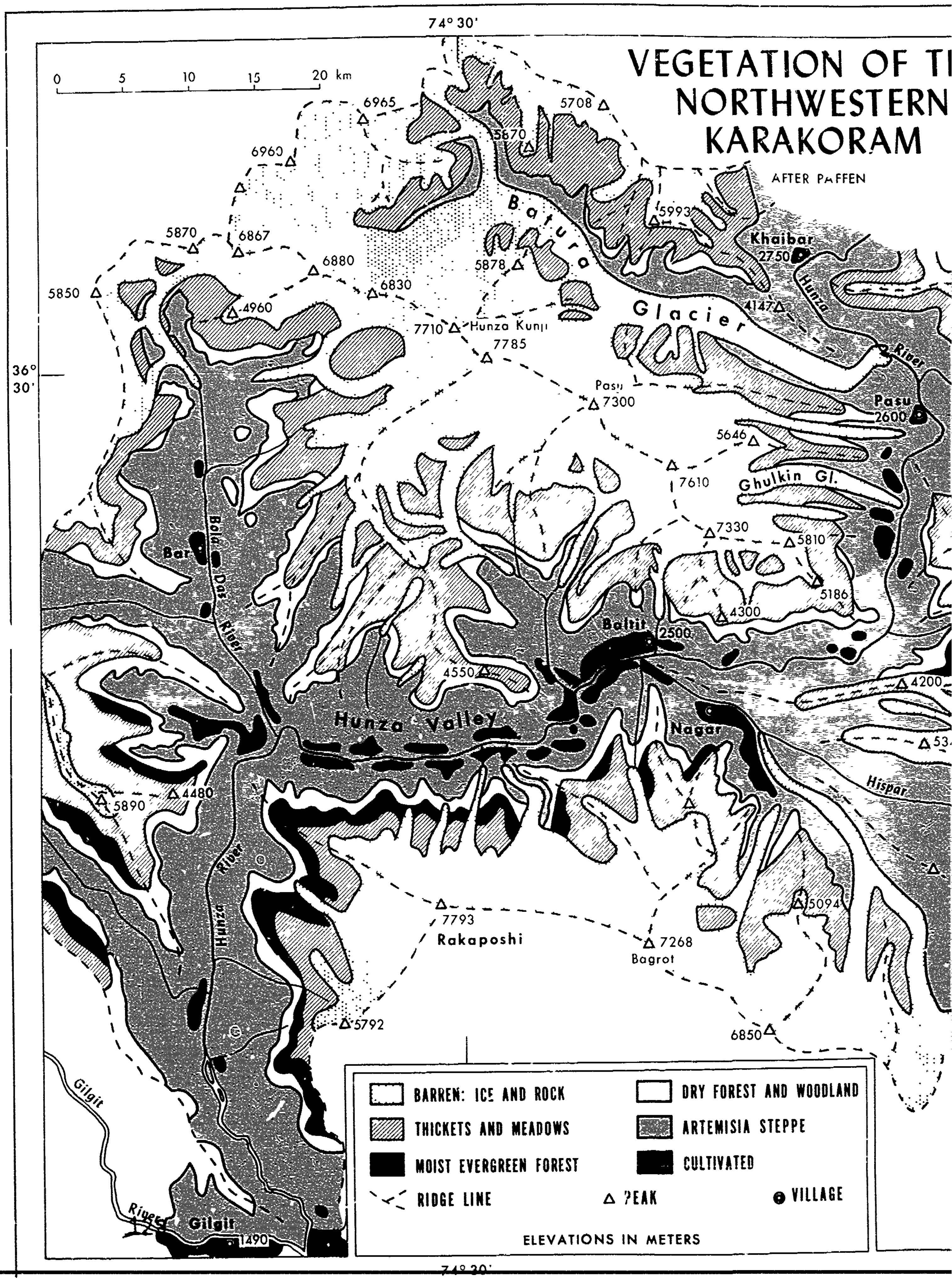
GLACIERS OF
U.S.S.R. PAMIR
0 10 20 30 40 50 60 KM
0 10 20 30 40 MI
Glaciers
Village
Pass
International Boundary
Peak
7495 Elevation in meters
Source Maps
AMS Asia sheet NJ-43, 1:1,000,000 (1953)
NJ-42 1:1,000,000 (1960)
Glaciation of Pamir, R D Zabirov, 1955
Russian Map, 1958 1:2,500,000
40°
70°
72°
38°
Daraut-Kurgan
Kyzyl-Su
Khait
Surkhob
Vakhsh
Muksu
Ters Agar P.
Sangvor
Tavil'-Dara
Ab-i-Panja
Buzin
LEDNIK YAGULEMSKIY
Vanch
Bartang
Tanymas
Kokuybel'
RUSHANSKIY
Khadgut
Yashil'kul
Gunt
Khorog
SHUGNANSKIY
Pamir
Pik Karla Marksa 6826
Pik Mayakovski 6095
VAKHANSKIY
Qala Panja
Mastuj
Map By American Geographical Society Under U.S. Army Contract


74°
76
Sary-T
Sary-Tash
Kyzyl-Su
Kara-kul'
Tanymas
Kokuybel'
Ak-Su
38
Sarala
BAZAR DARA
Nayzatash Pass
Tokhtamyshbek
Yashil'kul
Zor-Kul'
Pamir
Qala Panja
CHIANTAR
76
U.S.S.R.
CHINA
INDIA
LOCATION

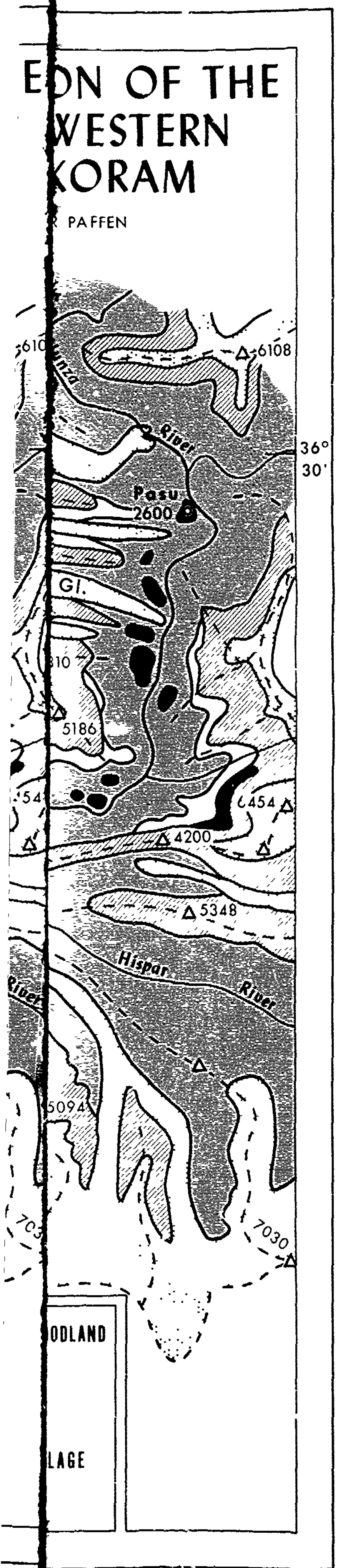


Chapursan
Karumbar Gl
Bhort Gl
Kukuar Gl
Baltar Gl
Pasu Gl
Ghujerab
Shimshal Pass
Ishkoman
Daintar
Hunza
Aliabad
Nagar
Biro Gl
Kurti Gl
Gilgit
Hispar
Haramosh Gl
Indus
Astor
Hattu Pir
Sachen Gl
Chhungphar Gl
Diamir Gl
Nanga Parbat
Bazhin Gl
Rupal Gah
H
I
M
A
Braldu
Shigar
Dras
LOCATION MAP
Principal Sources
Quarter Inch Series
(see text for other sources)
Map By American Geographial Society Under US Army Contract

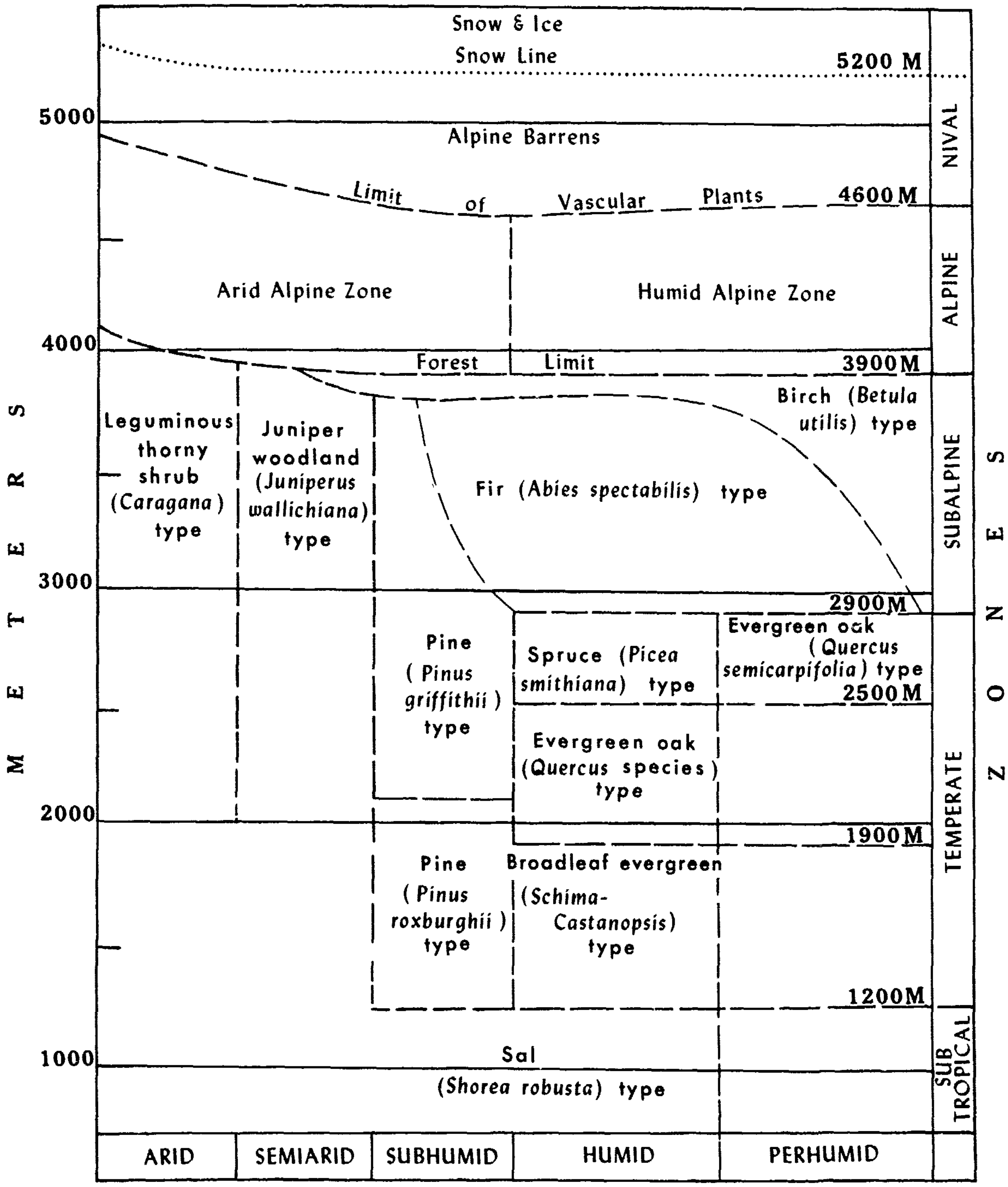

GLACIERS OF THE
KARAKORAM
30 MILES
0 10 20 30 40 KILOMETERS
861
Village
Yarkand
Aghil Pass
Gasherbrum G
Karakoram Pass 5570
Shyok
Indus
Nubra
Kichik Kumdan Gl
Aktash Gl
L A L A
LADAKH RANGE
76°
77°
78°
35°



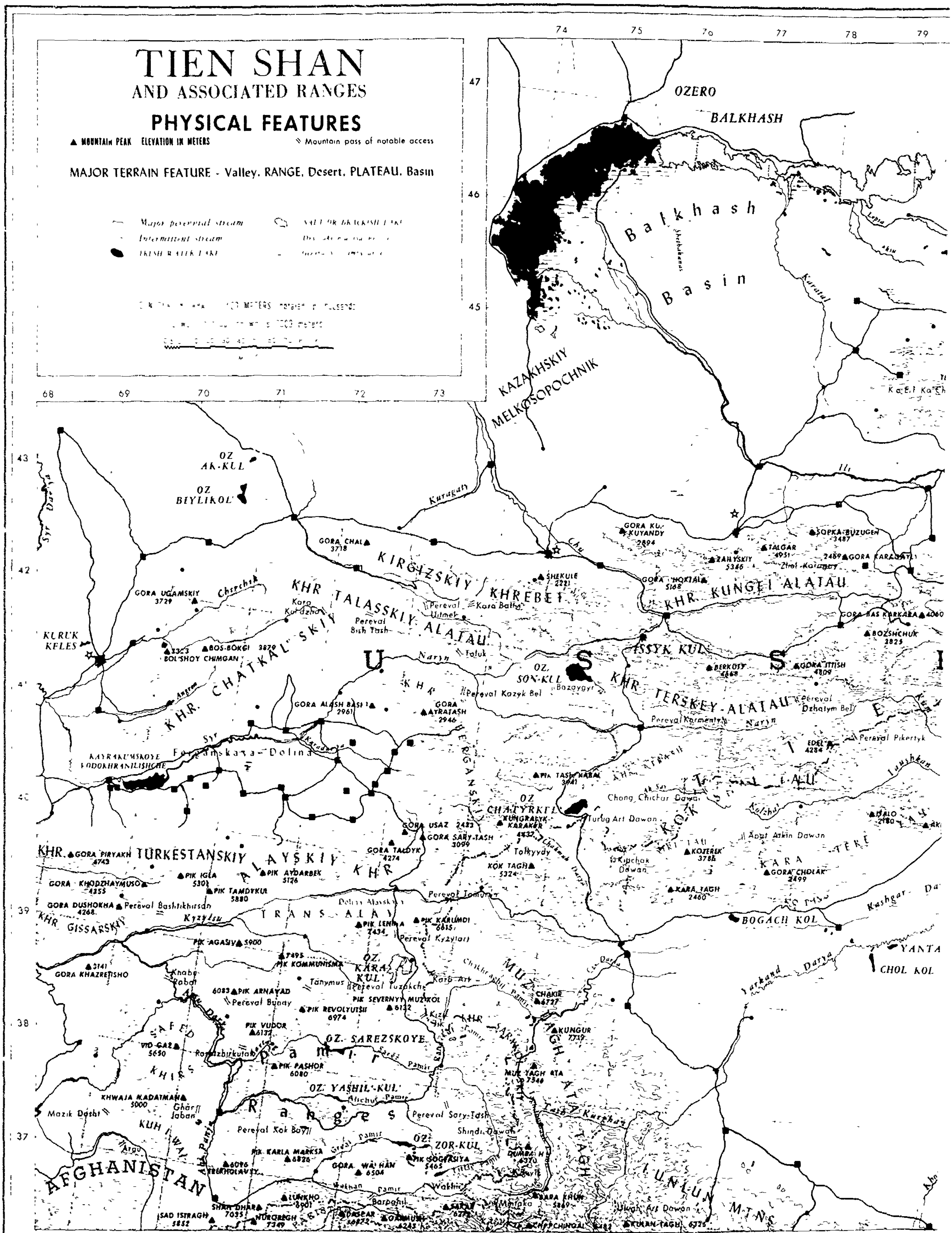
VEGETATION OF TH
NORTHWESTERN
KARAKORAM
AFTER PAFFEN
74° 30'
36° 30'
0 5 10 15 20 km
Batura Glacier
Hunza Kunji
Pasu
Ghulkin Gl.
Khaibar 2750
Pasu 2600
Baltit 2500
Hunza Valley
Nagar
Bar
Bola Das River
Hunza River
Hunza River
Hispar
Rakaposhi
Bagrot
Gilgit River
Gilgit 1490
BARREN: ICE AND ROCK
THICKETS AND MEADOWS
MOIST EVERGREEN FOREST
RIDGE LINE
DRY FOREST AND WOODLAND
ARTEMISIA STEPPE
CULTIVATED
PEAK
VILLAGE
ELEVATIONS IN METERS



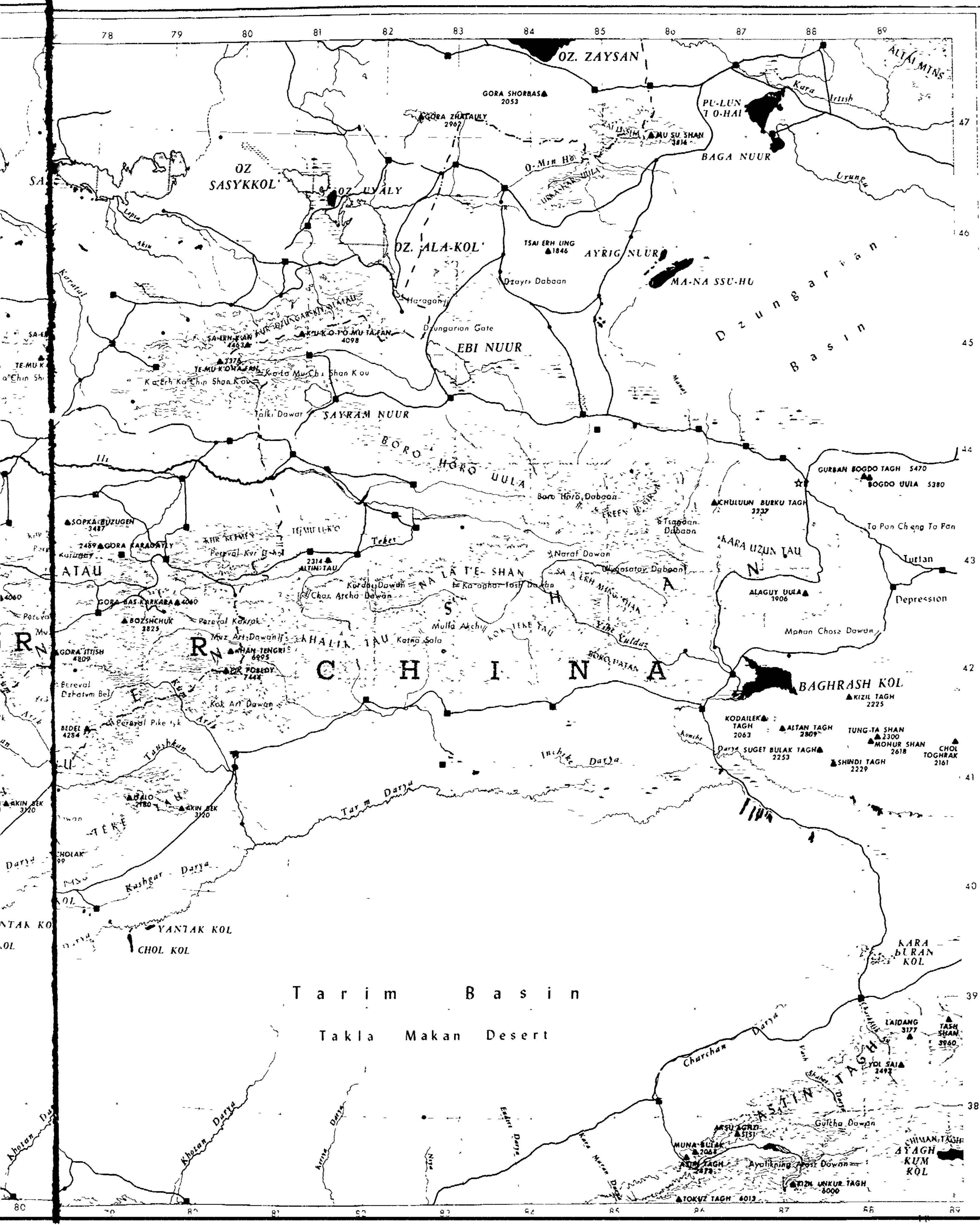
DIAGRAMMATIC DISTRIBUTION OF MAJOR VEGETATION TYPES IN CENTRAL NEPAL*



* after Kawakita



TIEN SHAN
AND ASSOCIATED RANGES
PHYSICAL FEATURES
MOUNTAIN PEAK ELEVATION IN METERS
Mountain pass of notable access
MAJOR TERRAIN FEATURE - Valley, RANGE, Desert, PLATEAU, Basin
OZERO BALKHASH
Balkhash Basin
KAZAKHSKIY MELKOSOPOCHNIK
OZ AK-KUL
OZ BIYLIKOL'
KIRGIZSKIY KHREBET
KHR TALASSKIY ALATAU
KHR. KUNGEI ALATAU
KHR. CHATKAL'SKIY
ISSYK KUL
OZ. SON-KUL
KHR. TERSKEY-ALATAU
Ferganskaya Dolina
OZ CHATYRKEL
KHR. TURKESTANSKIY
ALAYSKIY KHR
TRANS ALAY
KHR. GISSARSKIY
OZ. KARA KUL
OZ. SAREZSKOYE
OZ. YASHIL-KUL'
Pamir Ranges
OZ ZOR-KUL
SAFED KHIRS
KUH I WAKHAN
AFGHANISTAN
KASHGAR
BOGACH KOL
YANTA
CHOL KOL
KUNLUN MTNS
PIK LENINA 7134
PIK KOMMUNIZMA 7495
PIK KORZHENEVSKOY
PIK REVOLYUTSII 6974
GORA KHAN TENGRI


OZ. ZAYSAN
ALTAI MTNS
GORA SHORBAS
2053
GORA ZHATAULY
2962
PU-LUN
T O-HAI
Kara
Irtish
MU SU SHAN
3814
BAGA NUUR
Urungu
OZ
SASYKKOL'
OZ. UYALY
O-Min Ho
OZ. ALA-KOL'
TSAI ERH LING
1846
AYRIG NUUR
MA-NA SSU-HU
Dzayr Dabaan
Haragan
Dzungarian Gate
EBI NUUR
Dzungarian Basin
K'U-K'O-TO-MU TA-FAN
4098
SA-ERH-K'AN
4463
TE-MU-K'O-TA-FAN
Ka Erh Ka Chin Shan Kou
Ka-La Mu Chi Shan Kou
Talki Dawar
SAYRAM NUUR
BORO HORO UULA
Ili
Boro Horo Dabaan
GURBAN BOGDO TAGH 5470
BOGDO UULA 5380
CHULUUN BURKU TAGH
3237
Tsagaan Dabaan
To Pan Ch eng To Fan
SOPKA BUZUGEN
3487
GORA KARAGAYLY
2489
Pereval Kyr Bchol
Tekes
2314
ALTIN TAU
Naraf Dawan
KARA UZUN TAU
Turfan
NA LA T'E SHAN
Ulugasatay Dabaan
ALAGUY UULA
1906
Depression
Kurdai Dawan
Ka oghar Tash Dawan
Chas. Archa Dawan
GORA BAS-KARKARA 4060
BOZSHCHUK
3825
Pereval Kakrak
Mulla Akchi
KOK TEKE TAU
Yulduz
Manan Chosa Dawan
Muz Art Dawan
KHALIK TAU
Katna Sala
GORA ITTISH
4809
KHAN TENGRI
6995
PIK POBEDY
7439
BORO HATAN
CHINA
TIEN SHAN
BAGHRASH KOL
KIZIL TAGH
2225
Kok Art Dawan
KODAILEK
TAGH
2063
ALTAN TAGH
2809
TUNG-TA SHAN
2300
MONUR SHAN
2618
CHOL TOGHRAK
2161
BEDEL
4284
Pereval Pike Tik
SUGET BULAK TAGH
2253
SHINDI TAGH
2229
Konche
Darya
Inchike Darya
Taushkan
Tarim Darya
AKIN BEK
3120
KHOLAK
Kushgar Darya
YANTAK KOL
CHOL KOL
KARA BURAN KOL
Tarim Basin
Takla Makan Desert
LAIDANG
3177
TASH SHAN
3960
Charchan Darya
YOL SAI
3492
Vash Shahri Darya
ALTIN TAGH
ARSU AGRO
3151
Gulcha Dawan
MUNA BULAK
2061
Ayalikning Arsit Dawan
CHIMAN TAGH
AYAGH KUM KOL
KIZIL UNKUR TAGH
6000
TOKUZ TAGH 6013
Khotan Darya
Keriya Darya
Niya
Endere Darya
Kara Muran Darya
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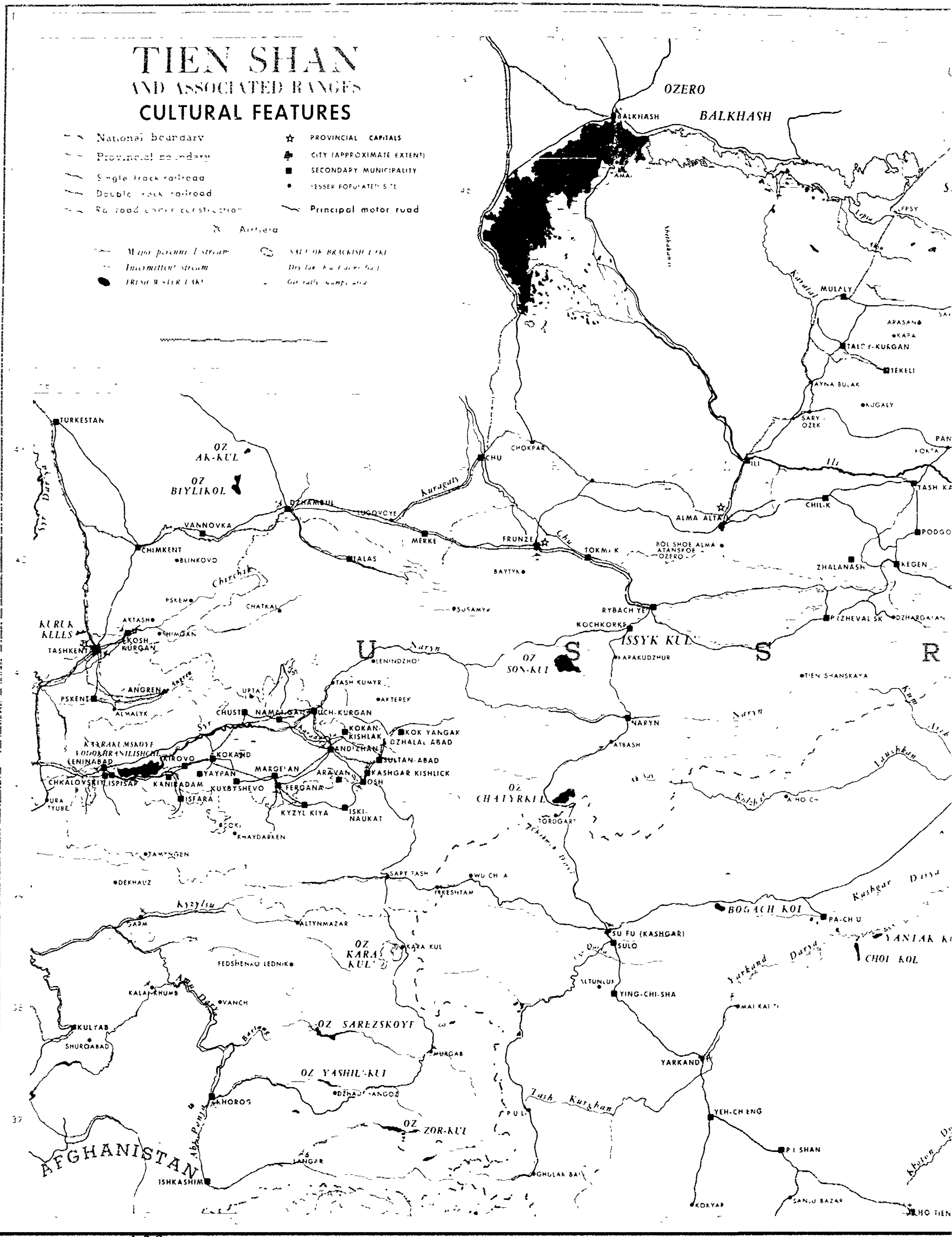
TIEN SHAN
AND ASSOCIATED RANGES
CULTURAL FEATURES
National boundary
Provincial boundary
Single track railroad
Double track railroad
Principal motor road
PROVINCIAL CAPITALS
CITY (APPROXIMATE EXTENT)
SECONDARY MUNICIPALITY
OZERO
BALKHASH
BALKHASH
MULALY
TALDY-KURGAN
TEKELI
SARY OZEK
ILI
Ili
ALMA ALTA
CHILIK
ZHALANASH
KEGEN
TURKESTAN
OZ AK-KUL
OZ BIYLIKOL
DZHAMBUL
LUGOVOYE
VANNOVKA
CHIMKENT
BLINKOVO
MERKE
TALAS
CHU
CHOKPAR
FRUNZE
TOKMAK
BAYTYK
Chu
Chirchik
CHATKAL
SUSAMYR
RYBACHYE
KOCHKORKA
ISSYK KUL
TASHKENT
AKTASH
ANGREN
PSKENT
ALMALYK
UPTAR
TASH KUMYR
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Naryn
OZ SON-KUL
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ATBASH
CHUST
NAMANGAN
UCH-KURGAN
KOKAN-KISHLAK
KOK YANGAK
DZHALAL ABAD
ANDIZHAN
SULTAN-ABAD
KASHGAR KISHLICK
OSH
LENINABAD
KIROVO
KOKAND
YAYPAN
MARGELAN
ARAVAN
CHKALOVSKIY
ISPISAR
KANIBADAM
KUYBYSHEVO
FERGANA
ISFARA
KYZYL KIYA
ISKI-NAUKAT
KHAYDARKEN
OZ CHATYRKUL
TORDGART
DEKHAUZ
SARY TASH
IRKESHTAM
Kyzylsu
GARM
ALTYNMAZAR
OZ KARA KUL
KARA KUL
FEDSHENKO LEDNIK
KALAI-KHUMB
VANCH
OZ SAREZSKOYE
KULYAB
SHUROABAD
MURGAB
OZ YASHIL-KUL
KHOROG
OZ ZOR-KUL
AFGHANISTAN
ISHKASHIM
LANGAR
Tash Kurghan
SU FU (KASHGAR)
SULO
BOGACH KOL
Kashgar Darya
YING-CHI-SHA
YARKAND
Yarkand Darya
YEH-CH ENG
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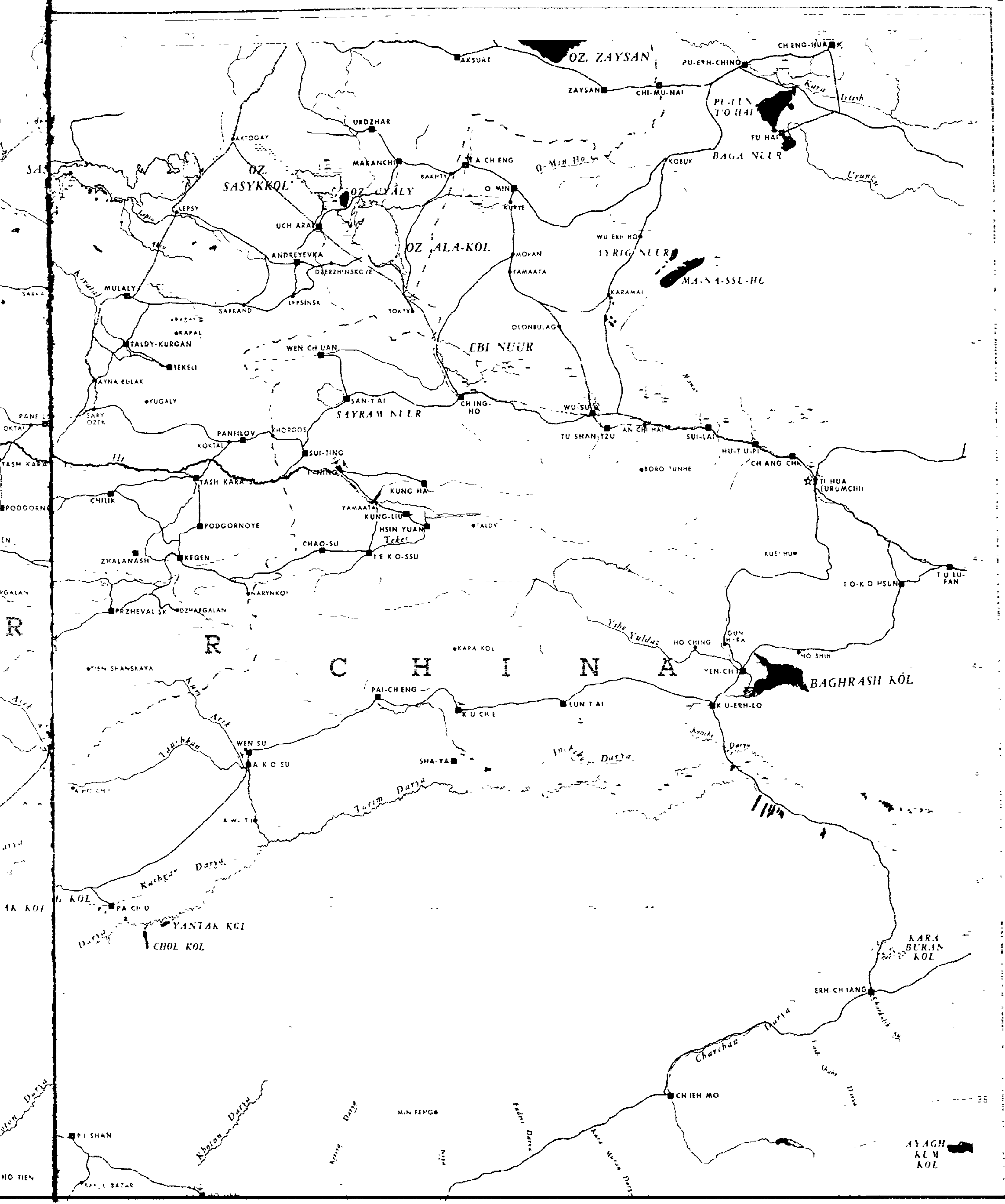
TIEN SHANSKAYA
PRZHEVALSK
TASH KA
PODGO



OZ. ZAYSAN
AKSUAT
ZAYSAN
CHI-MU-NAI
PU-ERH-CHING
CH ENG-HUA
PU-LUN
T'O HAI
Kara
Irtish
FU HAI
BAGA NUUR
Urungu
KOBUK
URDZHAR
AKTOGAY
MAKANCHI
BAKHTY
A CH ENG
O-Min Ho
O MIN
KURTE
OZ.
SASYKKOL'
OZ. ALA-KOL
LEPSY
Lepsy
UCH ARAL
ANDREYEVKA
DZERZHINSKOYE
WU ERH HO
TYRIG NUUR
MA-NA-SSU-HU
MORAN
YAMAATA
KARAMAI
MULALY
SARKAND
LEPSINSK
TOKTY
OLONBULAG
KAPAL
TALDY-KURGAN
TEKELI
WEN CH UAN
EBI NUUR
AYNA BULAK
KUGALY
SAN-T'AI
SAYRAM NUUR
CH ING-HO
WU-SU
SARY OZEK
PANFILOV
HORGOS
KOKTAL
TU SHAN-TZU
AN CHI HAI
SUI-LAI
HU-T'U-PI
CH ANG CHI
TI HUA (URUMCHI)
SUI-TING
Ili
I-NING
BORO TUNHE
TASH KARA
KUNG HA
CHILIK
YAMAATA
KUNG-LIU
PODGORNOYE
HSIN YUAN
TALDY
Tekes
CHAO-SU
TE K O-SSU
ZHALANASH
KEGEN
KUEI HUA
TU LU-FAN
T O-K O HSUN
NARYNKOL
PRZHEVAL SK
DZHARGALAN
R
Yulduz
HO CHING
GUN-H-RA
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KAPA KOL
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BAGHRASH KÖL
TIEN SHANSKAYA
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SHA-YA
Inchike Darya
Tarim Darya
Kashgar Darya
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PA CH U
YANTAK KOL
CHOL KOL
Darya
KARA BURAN KOL
ERH-CH IANG
Darya
Charchan
CHIEH MO
Darya
MIN FENG
Khotan Darya
P I SHAN
HO TIEN
AYAGH KUM KOL

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Appendix A

Some Comments on Climatic Stresses Caused by Elevation

a. Barometric Pressure

Without a doubt, the most influential climatic factor is that of barometric pressure. People react differently to the lower pressure experienced at high altitudes. Physiologists have explained many of the symptoms and reactions of mountain sickness. One of the better summaries of the effects of lowered barometric pressure is that given by Bert (1943):

> "At the beginning, a sensation of inexplicable fatigue, short respiration, rapid panting, violent and hasty palpitations; distaste for food; then buzzing in the ears, respiratory distress, dizziness, vertigo, weakness constantly increasing, nausea, vomiting, drowsiness, finally, prostration, dimming of the vision, various hemorrhages, diarrhea, and loss of consciousness. Such is the ascending series of symptoms, in proportion to the altitude reached .... Even death, an immediate death, may be the result of these serious symptoms .... The intensity of these symptoms is considerably aggravated by walking, running, and expenditure of energy."

Within the past few years, a team of U. S. Army military and civilian scientists made a clinical study of acute mountain sickness at a high-elevation Indian outpost in the Himalaya (Hall et al., 1965). They report:

> "Acute mountain sickness results from hypoxia, but the pathophysiology remains obscure. Some persons experience symptoms at elevations as low as 6,000 feet above sea level. Virtually all unacclimatized persons transported rapidly to altitudes of 15,000 feet or higher are affected. The cardinal manifestations are headache, breathlessness, and impaired capacity for exertion. These may be so severe and affect such a large proportion of exposed persons, that the effective performance of an unacclimatized group taken rapidly to high mountain altitudes will be markedly impaired. There is rapid clinical improvement, but full recovery of work performance equal to that at sea level is achieved slowly, if at all."

At the Interlaken Symposium on High Altitude Physiology, Inder Singh (1964) reported on some of the medical problems during high altitude acclimatization. He divided these problems into those resulting from adverse effects upon the body mechanism (dimness of vision, loosening of teeth, gastro-intestinal disturbances, lack of interest, insubordination) and those resulting from exhaustion or inadequacy of the beneficial body mechanisms (diminished output of work, loss of weight, gastro-intestinal disturbances - such as flatulence, indigestion, loose bowels, and pancreatic deficiency - thyroid deficiency, and severe and fatal infections).

In general, the journals show that men can become partially acclimatized to high altitudes if they are brought to high elevations in periodic and prolonged increments. It has been suggested that adaptation camps be established at 2,500, 3,500, and 5,000 m, with periods at these elevations of at least ten days duration. Pugh (1957) states that acclimatization cannot become complete for sea-level personnel above 5,000 m. It is most unlikely that the work capacity of even the best acclimatized man at such elevations can approach his sea-level productivity. The temporarily acclimatized, on the other hand, may be as productive as the native.

A certain amount of deterioration of acclimatization takes place at high altitudes. In contrast to acclimatization, which takes place in several weeks, deterioration is a much slower process involving several months. A good example of this deterioration was what happened to several of the wintering-over members at Silver Hut when they attempted to climb Makalu along with newly-arrived members of the expedition. The new members, who had been with the expedition about a month, were found to be in better climbing condition than those who had been there longer. To compensate for this deterioration, Indian troops maintaining daily outposts at elevations above 6,000 m are quartered at about 5,400 m and are rotated monthly downhill to an elevation of about 3,500 m. One must bear in mind that the soldier at high altitude becomes more of an individual than one at sea level where there is less variation in physiological responses. Of the eight mountaineer-scientists who wintered over at Silver Hut (elevation 5,800 m), one had to descend each week to a lower elevation and another had to do so every month. Imagine what would happen if a squad of soldiers, randomly selected, had been sent to this elevation. Unless there is a medical break-through in the prevention of mountain sickness, we cannot expect soldiers to function effectively above 5,500 meters.

b. Precipitation

Both precipitation and the lack of it can create stresses on personnel and materiel. As most of the study area comes under the influence of the monsoon, there is precipitation in summer and the winters are predominantly dry. The summer monsoon drops most of its moisture before it reaches the higher elevations. A good example of how the monsoon can fluctuate is the precipitation record for Lhasa, which is at 3,660 m (12,000 feet). In 1936 Lhasa received nearly 200 inches of precipitation, approximately eleven times that of its long-term average (Riordan, 1970). The maximum received in a 24-hour period was 11.7 inches, the most in one month being nearly 26 inches.

It is the extreme conditions with which the Army should concern itself in mountains, as annual averages often mask conditions which could stop an army. Flash floods, mudflows, and slides of all types can result from prolonged rains and heavy showers. In areas with steep local relief, debris from slides closes off roads and trails. Earthquakes are relatively frequent in certain parts of the Himalaya, and these often trigger slides of various types. Excessive ablation of snow fields or breaking of glacial dams can also result in severe flooding and considerable mass movement. Thus the stresses created by precipitation may be related only indirectly to the amount received during that year.

Transportation and maneuverability of man and his equipment are strongly influenced by precipitation, primarily through its effect upon stream flow and ground conditions. In cold dry regions with little cloudiness, such as the eastern Pamirs and northern Tibet, snow cover disappears rapidly and travel is much less difficult than might be expected. Regions of interior drainage contain swamps which hamper travel and breed insects, particularly in the spring, even though there is little precipitation. Salt playas, such as those in the Tsaidam Basin, are extremely treacherous when wet.

c. Temperature

The stress created by low temperature at high elevations is a major one, but one that is well understood and one with which the U. S. Army has had a degree of familiarization through its polar programs and operations. In the free atmosphere, the air temperature decreases approximately 1 C° for every 100-meter increase in altitude. The extreme minimum winter temperatures of the Arctic and Antarctic are missing in Central Asia, but the winter temperatures are still low enough to create a stress on the soldier.

Compared to the Arctic, wintertime minimum and maximum temperatures in mountains are higher; summertime minimum temperatures are lower; and maximum temperatures are higher. The relatively large diurnal temperature range in summer creates a clothing problem. Troops on duty at night at sites above 5,000 m can expect nocturnal minimum below freezing. At the same site, the black bulb radiation temperature in the day may be above 150° F. It is not at all uncommon, above 2,000 m, to experience mid-summer black bulb radiation temperatures greater than 100° F. Pugh cites a sun-shade temperature difference of 67 C° (100 F°) at 18,800 feet (5,370 m).

Although one may question the accuracy of some meteorological observations, one cannot doubt that the temperature difference experienced by anyone at high elevations can be extreme. A passing cloud can change the sensible temperature by tens of degrees. Stresses on personnel are usually created by extremes, not by means, and one should always be cognizant of expected extremes, their frequency, and their possible duration. It would seem that the most worthwhile uniform for high elevations in summer would include features which would first of all protect against the relatively low summer temperatures, but which would also allow for internal ventilation.

Man can function quite well for extended periods at temperatures as low as -20° F. In fact, men will probably function as long as mechanical equipment will support them at low temperatures. There are only three trouble zones (feet, hands, and face) in the protection of men against the cold, but unfortunately all three are sensitive and important. The most important zone is the feet, where the development of a thermo-electric system to warm insulated boots may solve the problem. The mechanism will have to be light and compact in order not to hinder the soldier's movements.

The second most important area is the fingers. The U. S. Army can put excellent polar mittens on the soldier which will protect him well below -100° F, but a satisfactory contact glove is not yet available for use when bulky mittens must be removed to squeeze a trigger. The repeated touching of one's fingers to cold metal objects will result in the formation of cornified layers of skin which will eventually peel. There are electrically heated woolen gloves on the market, but they have not been adopted by the Army.

The third area is the face, particularly the cheek bones and the end of the nose. None of the U. S. services has a satisfactory face mask, and probably the best thing for protecting the face from the cold is a relatively loose balaclava helmet. It is necessary to keep the balaclava loose, for when pressure is brought against the skin the circulation is restricted and it then becomes susceptible to frostbite. One of the advantages of the balaclava-type helmet is that the wearer has excellent vision, both forward and laterally. Strange as it may seem, moderately cold temperatures are more of a hazard than are much colder temperatures. At extremely low temperatures (colder than -20° F), a needle-like sensation is experienced when the skin on one's face is frostbitten and one can immediately massage it so that no damage will result; with more moderate temperatures, one does not experience this sensation and may end up with severe frostbite.

In addition to these three clothing problem areas, the rest of the mountain uniform has to be selected carefully. It has to be adequate for a relatively large diurnal temperature range, light in weight (not to exceed 20 pounds, including boots) so that the soldier will have some mobility, and of a tough fabric that will not easily tear on mountain outcrops, jagged rocks, and limbs of trees and shrubs. Because of the great interest in mountaineering throughout the world, there has been much development of civilian mountaineering clothing. However, many of these items are not sufficiently durable for wear in sustained combat.

d. Wind

Another climatic element creating a stress on personnel is wind, an element for which data are often misleading because of the sheltered location of most stations. Expedition accounts tell of winds of hurricane force, particularly at the summits of the giant peaks. One can discount the summit areas of mountains extending above 7,000 m. as military operations at such elevations would be most unlikely. Winds gusting to 60 knots were measured at Silver Hut (5,800 m), although the maximum sustained wind was only 35 knots.

Winds above 15 knots, when combined with temperatures below -20° F and a snow surface, produce severe environmental stresses. Depending upon the nature of the snow, one can normally expect snow movement to begin at wind speeds around 15 knots. When winds increase to around 25 knots, there will be a considerable amount of blowing snow. In fact, this could be considered the wind threshhold restricting travel over snow. However, the quantity, crystal type, moisture, density, hardness, age, and other factors influence the speed threshholds for both drifting and blowing snow.

Blowing snow creates more of an operational stress as it restricts both visibility and mobility. The combination of high winds and low temperatures creates a chilling effect which will be discussed in the next paragraph. High winds alone are chiefly a nuisance to the soldier in mountain areas and it is only when they are combined with low temperatures that they create a severe environmental stress. In addition to this stress, a minor one is created by blowing dust and/or fine gravel in the atmosphere at the operational level (near the ground) in the highlands of Afghanistan, the Pamirs, and the northern and northwestern parts of the Tibetan Highlands.

There has been a lot of discussion of what constitutes the best indicator of the severity of a climate. The U. S. Army has used windchill computations to determine clothing requirements in polar climates. However, this index has severe limitations; it is a raw computation based solely upon temperature and wind speed, and it takes no account of radiation or of atmospheric moisture. Within recent years the U. S. Army has used the Davos frigorimeter at some of its cold stations. This instrument, a black copper sphere whose temperature is maintained at the deep body temperature of man, takes solar radiation temperature and wind speed into account, and, in addition, is influenced by moisture/precipitation.

A case can be made for including the Davos frigorimeter as a standard item in the military meteorological system. Although the complete unit is not manually portable and requires a power system, it could be modified into a back-pack item. It has been used in Europe since the late 1920's, and once the instrument has been installed, a minimum of maintenance is required. Physiological limits have never been determined for the frigorimeter and this must be done before the data will be generally usable by the Army. When these limits are established, some sort of an altitudinal factor must be introduced, as man is certainly more susceptible to cold injury at higher elevations than he is at sea level.

e. Solar Radiation and Cloudiness

Solar radiation experienced at high elevation is much more intense than at sea level. This results from the thinness of the aerosol-filled layers of the air at high elevations. With clear skies, the total sun plus sky radiation increases approximately 1% for every 100-meter increase in elevation; with overcast skies, the increase with height is approximately 4% per 100 meters because of the diffused radiation (Geiger, 1965).

The quantity of radiation received at a given place is a function of latitude, declination of the sun, altitude of the sun, angle of slope, direction of slope, screening, and reflectivity. On sunny days, fabric colors will fade more rapidly and cameras with focal plane shutters must never be turned skyward with the diaphragm open. Only seconds are required to burn or melt a hole through such shutters when the sun's rays are concentrated by the lens. Cameras are also among the many delicate instruments and weaponry which can jam or become permanently damaged by ice crystal formation in moving parts when operating under a cloud cover.

A southward-facing slope of 20° can receive twice as much radiation in mid-winter as a horizontal surface. Screening occurs when the horizon is obscured by mountains, thus cutting down the period with radiation. As the atmosphere decreases in mass with higher elevation, direct solar radiation intensities increase. Very high radiation values are obtained at high elevations under partly cloudy sky conditions, as the amount reflected from clouds, added to that coming through gaps in the clouds, can result in instantaneous readings above that of the solar constant. Untersteiner (1958) has made measurements of 2.6 and 2.4 cal cm^{-2} min^{-1} for a height of 6,400 m at Karakoram Camp, and at 4,300 m on Chogo Lungma Glacier. However, the maximum measurement at Silver Hut Camp 5,800 m (near Mt. Everest), was only 1.65 cal cm^{-2} min^{-1} (Bishop et al, 1965).

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What does this mean to the soldier? Basically, it reduces to the fact that he can be quite comfortable with subfreezing temperatures down to -25° F if the sun is shining. Once the sun is shut out by a passing cloud, an individual immediately feels cold. The same thing happens at sunset, but more gradually. Consequently, people at high elevations should be prepared not only for large diurnal ranges but also for sudden, abrupt changes. If a continuous deck of stratiform cloud hangs over the mountains for an extended period, it will not only serve to shut off the direct short-wave radiation but will also act as a blanket and will trap some of the outgoing long-wave radiation and thereby warm the layer between the surface and the bottom of the cloud deck.

An overcast sky over a snow surface can create "whiteout" conditions, obliterating the horizon. All air traffic then has to be shut down, as flying in such conditions in a mountain area would be disastrous. However, it is also a period when troop movements can be executed without being observed from above. Most white-outs are not so severe as to restrict horizontal movement, as dark objects can be picked out.

The protection of one's eyes at high elevations, particularly over snow, is another problem. Snow blindness can result when an individual fails to use his goggles. The critical factor here appears to be the elevation angle of the sun, as a low sun (less than 15° above the horizon) will not do the harm that a higher sun will. Snow blindness is a painful experience and keeps a man from active duty for several days while he lies in a darkened room. It is also an unnecessary happening, as one should always wear goggles at high elevations. Mirror-surfaced goggles are not recommended for military use as they reflect light and can easily give away one's position. The combination of strong solar radiation, low relative humidity, and strong winds also affects the skin, causing burning, drying, and cracking. Facial creams and chap sticks are standard protective items at high elevations.

Cloudiness in mountain regions can be a depressant. The human being finds conditions much more pleasant when he is able to see where he is and where he is going. On the other hand, an atmosphere of fog or clouds dampens his outlook and may become most unpleasant when the cloud particles approach the freezing temperatures of high elevation. In many mountainous areas the problems with clouds are of a local nature, related directly to local topography. Low clouds would be generally of stratus type. Monsoon clouds are usually stratiform, rarely reaching above 2,000 m. Middle clouds (above 3,000 m) are more extensive. Sky conditions improve above 5,000 m as high clouds are above the mountain peaks and have little effect on a person's comfort. It is the clouds of low elevation that have the most adverse effect on personnel.

Appendix B

CLIMATIC STATION LIST
PART I: 2000 meters or higher

Station	N. Lat.	E. Long.	Meters Elev.	Years of Record Temp.	Years of Record Precip.
Adag Mamar	32 00	92 10	4000	5	0
Apa	32 43	102 18	2750	5	5
Chahanwusu	36 10	98 16	3400	5	0
Chakrata	30 42	77 51	2149	0	12
Changtu (Chamdo)	31 10	97 14	3200	8	4
Chienning (Taining)	30 34	101 30	3496	1	0
Chitinghsilin	32 51	92 28	5049	1	0
Chiulung	28 59	101 32	2880	5	0
Dalhousie	32 32	75 59	2343	0	m
Darjeeling	27 02	88 16	2265	50	60
Depsang	35 17	77 58	5362	1	0
Dras	34 27	75 46	3066	40	40
Gartok	31 45	80 22	4602	6	1
Ghazni	33 33	68 26	2218	m	m
Gnatong (Natang)	27 15	88 50	3749	m	o
Gulmarg	34 03	74 23	2654	0	40
Gyangtse (Chiangtzu)	28 57	89 38	3996	5	5
Hanle	32 48	79 00	4610	m	m
Hsiaho (Tewulu)	35 14	102 30	3049	2	0
Hsiaochin	31 01	102 23	24665	4	4
Hsining	36 35	101 55	23880	13	8
Huachialing	35 27	104 47	2440	5	5
Huanghoyen (Mato)	34 57	98 08	3873	8	3
Huashan	34 27	110 05	2074	4	3
Irkeshtam	39 41	73 55	2850	30	30
Kaerhmu (Karmu)(Golmo)	36 22	94 55	2850	5	0
Kalat	29 02	66 37	2017	20	55
Kangting (Tatsienlu)	30 03	102 02	2558	9	14
Kantzu	31 38	100 01	3320	10	5
Karakul	39 02	73 33	3912	1	1
Kargil	34 44	76 08	2682	30	30
Khorog (Chorog)	37 30	71 36	2098	22	22
Khuitun Nor (Lenghu)	38 55	93 12	2773	1	0
Kukushihli	35 17	93 02	4267	2	0
Kungho (Chiapuchia)	36 21	100 47	3105	8	2
Leh	34 09	77 34	3514	60	60
Lhasa	29 39	91 06	3685	16	14
Likiang (Lichiang)	26 57	100 18	2416	6	6
Litang (Lihua)	30 00	100 16	4187	5	0
Lungtzu (Lhuntse)	28 26	92 27	3000	1	0

Appendix B

CLIMATIC STATION LIST
PART I: 2000 meters or higher
(continued)

Station	N. Lat.	E. Long	Meters Elev.	Years of Record Temp.	Years of Record Precip.
Malkang	31 51	102 41	2600	5	0
Mangyai	37 50	91 38	2800	4	0
Minhsien	34 30	104 02	2246	12	14
Mukteswar	29 28	79 39	2314	40	40
Murree	33 55	73 23	2168	50	60
Mussoorie	30 27	78 05	2115	10	15
Naryn	41 26	76 00	2049	51	63
Niti	30 42	79 51	3231	0	1
Omeishan	29 28	103 21	3358	11	11
Pahsaichaitamuh (Tachaitan)	37 50	95 17	3350	1	0
Pamirsky Post (Murgab)	38 11	74 02	3653	22	22
Patang (Pa-an) (Batang)	30 05	98 55	2700	8	7
Phari Dzong (Pali) (Pharitsung)	27 45	89 10	4420	5	0
Puri (Pu)	31 46	78 35	3000	0	m
Sarytash	39 44	73 15	3128	0	m
Sewukou (Chumalai)	34 35	95 18	4262	1	0
Simla	31 06	77 10	2202	45	60
Skardu	35 18	75 37	2288	40	40
Sohsien (Sotsun)	31 51	93 40	4000	1	0
Sonamarg	34 19	75 19	3560	0	40
Sungpan	32 39	103 54	2856	8	8
Tag Dzong (Panko)(Tagtsung)	32 00	89 30	4663	1	0
Tajih (Chimai)(Chinai)	33 55	99 52	3600	5	0
Tali	25 42	100 11	2001	11	10
Tanpa	30 57	101 55	3000	0	1
Tejung	28 46	99 19	2700	0	1
Telingha (Tehlingha)	37 15	97 00	2761	5	0
Tien Shanskaya (Tjan San)	41 55	78 14	3614	m	m
Tingching (Techin)	31 32	95 26	4000	4	0
Tulanssu (Dulaan)	37 01	98 46	3075	5	5
Tungte	35 10	100 40	2744	5	0
Walungchung Gola	27 45	87 37	3165	0	m
Wuhsiaoling	37 11	103 05	3045	5	5
Yatung (Chumbi)	27 29	88 54	2987	45	45
Yushu	33 01	96 44	3873	5	2
Yuyujihpen	33 09	94 43	4000	1	0
Zhikatse (Jihkotse)	29 15	88 53	3660	1	0

m = length of record missing from data sources used

CLIMATIC STATION LIST
PART II: Below 2000 meters

Station	N. Lat.	E. Long.	Meters Elev.	Years of Record Temp.	Years of Record Precip.
Aktash	41 40	69 48	1135	11	11
Akterek (Akterek Gave) (Akterek Pass	40 24	73 30	1800	m	m
Alma Ata	43 16	76 53	841	47	47
Altayskaya	49 10	85 34	1000	18	18
Anantnag	33 43	75 07	1597	0	47
Baytyk	42 44	74 30	16155	14	14
Chatchil (Khatkyl) (Hadhal)	50 03	100 05	1637	3	4
Chengtu (Tungchwang)	30 40	104 04	498	21	21
Cherat	33 49	71 53	1302	45	45
Cherrapunji	25 15	91 44	1313	35	35
Chitral	35 55	71 56	1672	14	31
Chiuchuan	39 46	98 34	154	18	18
Dalan Dzadagad	43 35	104 25	1981	1	7
Drosh	35 34	71 47	1435	40	40
Durekchi Van (Tesiin Huryee)	49 38	97 24	1668	3	0
Fort Sandeman	31 20	69 27	1406	25	25
Gilgit	35 55	74 23	1490	45	45
Haka	22 39	93 37	1860	10	10
Herat	34 20	62 10	922	m	m
Hsichangg	27 53	102 18	1597	11	17
Hsinghsinghsia	41 47	95 07	1776	3	3
Huili (Hweili)	26 50	102 15	1920	3	7
Kabul	34 31	69 12	1954	9	45
Kalimpong	27 04	88 29	1208	20	15
Kandahar	31 36	65 41	1044	m	m
Kashg (Sufu) (Koshih)	39 31	75 45	1410	3	3
Katmandu	27 42	85 12	1337	40	6
Khotan (Hotien)	37 07	79 55	1387	2	3
Kilba	31 31	78 09	1525	0	m
Kobdo (Jirgalanta)	47 59	91 35	1300	3	6
Kopal (Kapal)	45 08	79 03	1239	36	36
Kosh Agach	50 00	88 40	18	2	m
Kuche (Kucha)	41 45	83 04	1100	5	5
Kunming (Yunnanfu)	25 07	102 54	1893	20	20
Lanchou	36 03	103 59	1508	19	19
Lenindzhol	41 04	72 38	700	m	m
Markakul	48 42	85 30	1410	3	7
Mondy	51 40	100 59	1310	9	6

CLIMATIC STATION LIST
PART II: Below 2000 meters
(continued)

Station	N. Lat.	E. Long.	Meters Elev.	Years of Record Temp.	Years of Record Precip.
Okinski Stan	52 41	99 41	1276	4	4
Olenya Rechka	52 48	93 14	1225	5	m
Orlovski Poselok	48 44	86 32	1084	7	7
Osh	40 32	72 48	1023	45	
Paotou	40 34	109 50	1044	5	5
Parachinar	33 54	70 06	1729	24	40
Pendzhikent	39 30	67 37	990	13	13
Perevalnaya	51 44	112 37	1624	12	10
Przhevalsk (Karakol) (Kara Jilga)	42 29	78 24	1770	32	45
Quetta	30 15	66 53	1601	73	773
Sayn Shanda	44 52	110 09	1189	7	0
Shillong	25 34	91 53	1500	48	10
Srinagar	34 05	74 50	1587	50	50
Tashkent	41 20	69 18	478	56	56
Tihua (Urumchi) (Wulumochi)	43 48	87 35	913	5	5
Tsetserlig (Zezerlik)	47 28	101 28	1687	2	0
Tunhuang (Tunwhang)	40 08	94 47	1139	12	12
Ulan Bator (Urga)	.47 55	106 50	1322	26	2
Ulyassutai (Jibhalanta)	47 44	96 52	1719	3	0
Verkhnyaya Mishikha	51 30	105 58	1280	8	8
Wutu	33 23	104 41	1090	5	3
Wuwei (Liangchow)	38 05	102 55	1475	9	11
Yenchi (Karashahr)	42 04	86 34	1058	3	3
Yunnan Sen (Hsianyun)	25 29	100 35	1980	2	2
Zaysan	47 31	85 01	557	22	22

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m = length of record missing from data sources used

Appendix C

CHECKLIST OF CENTRAL ASIAN MOUNTAIN PEAKS WHICH EXCEED 7,000 METERS

Key to Mountain Systems:

- AH - Assam Himalaya (1)
- AK - Aling Kang Ra. (Alung Gangri)
- CW - Chao Wula Shan
- HK - Hindu Kush
- KA - Karakoram-Aghil
- KH - Kumaun Himalaya (2)
- KL - Kun Lun-Arka Tagh
- MA - Muztagh Ata
- MD - Monts Dupleix
- NH - Nepal Himalaya (3)
- NT - Nyenchen Tanglha
- PH - Punjab Himalaya (4)
- PR - Pamir Ranges
- SH - Sikkim Himalaya (5)
- TH - Ta Hsueh Shan (Gt. Snowy Range)
- TS - Tien Shan
- TV - Located in the Trans-Himalayan Vales apart from great range systems

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(1) From Sikkim to the great bend of the Brahmaputra River in Tibet/Assam
(2) East of the Sutlej and west of the Kali rivers
(3) State of Nepal (Kali River to Sikkim) in Nepal/Tibet
(4) East of the Indus and west of the Sutlej Rivers, all in Punjab
(5) State of Sikkim (Nepal to Bhutan) in Sikkim/Nepal/Tibet

Elevations (in meters) are approximations except on peaks which have been climbed.

1	Everest (Chomolungma I)	NH	8848
2	Godwin-Austen (K-2)	KA	8611
3	Kanchenjunga I	SH	8585
4	Lhotse I	NH	8501
5	Makalu I	NH	8481
6	Kanchenjunga II	SH	8474
7	Lhotse II	NH	8400
8	Everest (Chomolungma II)	NH	8393
9	Lhotse Shar	NH	8383
10	Broad Peak I	KA	8270
11	Dhaulagiri I	NH	8172
12	Manaslu I	NH	8156
13	Cho Oyu	NH	8153
14	Nanga Parbat I	PH	8129
15	Annapurna I	NH	8078
16	Gasherbrum I (Hidden Peak)	KA	8068
17	Gasherbrum II	KA	8035
18	Gosainthan I(Shisha Pangma)	NH	8013
19	Gasherbrum III	KA	7952
20	Lamjung	NH	7937
21	Annapurna II	NH	7937
22	Broad Peak II	KA	7930
23	Gasherbrum IV	KA	7925
24	Gyachung Kang	SH	7922
25	Kangbachen	SH	7902
26	Disteghil Sar I	KA	7885
27	Himal Chuli I	NH	7864
28	Khinyang Chhish	KA	7852
29	Ngojumba Kang	NH	7843
30	Nuptse	NH	7841
31	Manaslu II	NH	7835
32	Masherbrum East	KA	7821
33	Nanda Devi West	KH	7817
34	Chomo Lonzo	NH	7815
35	Nanga Parbat II	PH	7814
36	Masherbrum West	KA	7806
37	Rakaposhi	KA	7788
38	Hunza Kunji I	KA	7785
39	Zemu	SH	7780
40	Kanjut Sar I	KA	7760
41	Kamet I	KH	7756
42	Namcha Barwa I	AH	7755
43	Singhi Kangri	KA	7751
44	Dhaulagiri II	NH	7751
45	Saltoro Kangri I	KA	7742
46	Gurla Mandhata (Memo Nani)	NH	7725
47	Ulugh Muztagh	KL	7724
48	Kungur	MA	7719
49	Kumbhakarna (Janu)	NH	7710
50	Hunza Kunji II	KA	7710

Appendix C

CHECKLIST OF CENTRAL ASIAN MOUNTAIN PEAKS WHICH EXCEED 7,000 METERS (Continued)

51	Saltoro Kangri II	KA	7705
52	Dhaulagiri III	NH	7703
53	Tirich Mir	HK	7699
54	Disteghil Sar II	KA	7696
55	Saser Kangri I	KA	7672
56	Gosainthan II	NH	7661
57	Makalu II	NH	7657
58	Chigolisa I	KA	7654
59	Himal Chuli II	NH	7645
60	Dhaulagiri IV	NH	7640
61	Dzagar	CW	7620
62	Tupeilikossu I (Dupleix)	MD	7620
63	Ghulkin North	KA	7611
64	Rathong	SH	7593
65	Minya Konka	TH	7589
66	Peak 38 (near Lhotse)	NH	7587
67	Annapurna III	NH	7577
68	Kula Gangri	AH	7554
69	Changtse	NH	7553
70	Muztagh Ata	MA	7546
71	Skyang Kangri	KA	7544
72	Gangri I	AH	7541
73	Mamostang Kangri	KA	7526
74	Gangri II	AH	7516
75	Shukpa Kunchang	KA	7513
76	Tupeilikossu II	MD	7508
77	Annapurna IV	NH	7507
78	Peak 38 SE	NH	7502
79	Jakthang Gangri	AK	7500
80	Kabru South	SH	7498
81	Pik Kommunisma (Stalina)	PR	7495
82	Saser Kangri II	KA	7495
83	Pumarikis	KH	7492
84	Tupeilikossu III	MD	7488
85	Noshaq	HK	7485
86	Chumik I	KA	7469
87	Teram Kangri I	KA	7464
88	Jonsang	SH	7459
89	Malubiting	KA	7458
90	Gyala Peri I	AH	7450
91	Pik Pobedy	TS	7439
92	Nanda Devi East	KH	7434
93	Pik Lenina	PR	7434
94	Chumik II	KA	7428
95	Sia Kangri I	KA	7422
96	Dome Kang	SH	7420
97	Saser Kangri III	KA	7416
98	Teram Kangri II	KA	7407
99	Salasungo Danda	NH	7406
100	Kondus I	KA	7401
101	Istoro Nal	HK	7398
102	Haramosh	KA	7397
103	Trivor	KH	7393
104	Talung South	SH	7388
105	Rimo Muztagh I	KA	7385
106	Teram Kangri III	KA	7382
107	Tent Peak	SH	7365
108	Churen Himal	NH	7363
109	Manaslu III	NH	7361
110	Abigamin	KH	7355
111	Nuroregh Zom	HK	7349
112	Talung North	SH	7349
113	Paitju	NH	7346
114	Momhil Sar I	KA	7343
115	Staircase Peak	KA	7339
116	Kabru North	SH	7338
117	Nalakankar	NH	7335
118	Chongstar	KA	7330
119	Ghulkin South	KA	7329
120	Alung Gangri I	AK	7324
121	Chamlang	NH	7319
122	Temo SE	AH	7315
123	Jomolhari (Chomo Lhari)	AH	7314
124	Baltoro Kangri (Golden Throne)	KA	7312
125	Sherpi Kangri	KA	7303
126	Karicham	AH	7300
127	Duzakh Tagh	KL	7291
128	Pasu	KA	7284
129	Baltistan	KA	7282
130	Muztagh K-5	KL	7281
131	Muztagh Tower	KA	7279
132	Baruntse I	NH	7276
133	Mana	KH	7273

Appendix C

CHECKLIST OF CENTRAL ASIAN MOUNTAIN PEAKS WHICH EXCEED 7,000 METERS
(Continued)

134	Nodzinkangsa I	TV	7252
135	Langtang Lirung	NH	7245
136	Apsarasas I	KA	7245
137	Mukut Parbat	KH	7242
138	Baruntse II	NH	7240
139	Putha Hiunchuli	NH	7239
140	Gangri III	AH	7239
141	Apsarasas II	KA	7239
142	Apsarasas III	KA	7235
143	Rimo Muztagh II	KA	7233
144	Kuhanbokano	AK	7216
145	(Unnamed) northern Bhutan	AH	7212
146	Khartaphu	NH	7205
147	Baruntse III	NH	7200
148	Saltoro Kangri III	KA	7200
149	Momhil Sar II	KA	7199
150	Jugal Himal	NH	7195
151	Bagrot I	NH	7194
152	Nodzinkangsa II	TV	7188
153	Gauri Sankar East	NH	7181
154	Laptshegang	NH	7178
155	Sringe H-mal	NH	7177
156	Dhaulagiri V	NH	7175
157	Rimo Muztagh III	KA	7169
158	Nepal Peak	SH	7168
159	(Unnamed) SE Tibet	AH	7163
160	(Unnamed twins) NW Bhutan	AH	7161
161	Gyala Peri II	AH	7152
162	Hardeoi	KH	7151
163	Pumori	NH	7145
164	Gauri Sankar West	NH	7144
165	Nun	PH	7140
166	Chaukhamba (Badrinath)	KH	7138
167	Pyramid Peak	SH	7133
168	(Unnamed) NW Bhutan	AH	7133
169	Ganesh Himal	NH	7132
170	Api	NH	7132
171	Himlung Himal	NH	7126
172	Pauhunri (Pauhunghri) I	SH	7125
173	Pabil	NH	7120
174	Trisul	KH	7120
175	Front Peak (Nanga Partat)	PH	7118
176	Namcha Barwa II	AH	7110
177	Chepanglik	KL	7102
178	Targot (near Tangra Lake)	NT	7100
179	Sia Kangri II	KA	7093
180	Kamet II	KH	7092
181	Kun	PH	7091
182	The Outlier	SH	7090
183	Changtok South	KA	7090
184	Kangto	AH	7089
185	Nyencnhentanglha	NT	7088
186	Satopanth	KH	7075
187	Tirsuli	KH	7074
188	Shelkar Chorten I	KA	7071
189	Rakhiot	PH	7070
190	Dunagiri	KH	7066
191	Khartachangri I	NH	7065
192	Nuroregh North (NZ-2)	HK	7062
193	Lombo Kangra	NH	7061
194	Chomo Gangri (in Lunkar Ri)	NT	7060
195	Purbi Dunagiri	KH	7050
196	Nyegyi Kangtsang	AH	7047
197	Changtok North	KA	7044
198	Isnekanj	NH	7043
199	Matachumba	NH	7043
200	Tabsar	NH	7040
201	Shah Dhar	HK	7038
202	Saipal	NH	7034
203	Knartachangri II	NH	7032
204	Yanghi Tagh	KL	7032
205	Pauhunri II	SH	7032
206	Nilgiri North	NH	7031
207	Nupchu Chabuk	NH	7028
208	Chogo Lungma	KA	7027
209	Shilla	PH	7026
	Aconcagua (highest in Americas)	Arg.	7021
210	Kumdan	KA	7016
211	Sanglung	AH	7015
212	Amne Denve	CW	7010
213	Shelkar Chorten II	KA	7004
214	Tilje North	NH	7001
215	Chomo Gangar	NT	7000
216	Namla Karpo	AH	7000
217	Machhapuchhare	NH	6998
218	Khan Tengri	TS	6996
219	Aghil Tagh	KA	6995
220	Noghor Zom	HK	6994

7000 meters = 22,966 feet (4.35 miles)

(Mount Everest (8,848 m) = 29,030 feet or 5.50 miles above mean sea level)

Appendix D

A NOTE CONCERNING PLACE NAMES

Since the study area includes a number of countries and languages, none of which uses the Roman alphabet, it is inevitable that there should be several ways of rendering most place names. The situation is further complicated by the fact that changes in sovereignty or political control of an area often bring changes in official place names as well. This applies chiefly to the names of cities and other political units, but natural features of the landscape are not exempt from such changes, as, for example, the change of "Mt. Stalin" to "Pik Kommunisma" that resulted from an internal shift in Soviet policies.

Because of differing data sources and differing purposes of the various maps in this report, there is not complete uniformity from one map to another. In general, place names shown on the larger-scale maps (Maps 15-25) follow practices of the U. S. Board on Geographic Names. These names follow the official usage of the country concerned, as rendered by rigid rules of transliteration. For example, Lake Baikal is shown in the Russian form as "Ozero Baikal" and the Altai Mountains are given in the Mongolian form as "Altayn Nuruu." To facilitate understanding of the text, however, Anglicized forms of many place names are used in the text and in the orientation maps (especially Maps 1 and 2). These are the forms that generally appear in the source literature and in such standard sources as the National Geographic Society maps, the Columbia-Lippincott Gazeteer, and the Times Atlas. Their use here thus will aid in referring to the sources and to the more widely used atlases. In citing climatological stations it is especially important that station names be given in the same form as in the source, even when the names have since been changed.

It is usually a fairly easy matter to determine the equivalence of indigenous and Anglicized place names. Where this is not obvious, or where names have been changed, reference to the following tables will be of assistance. The first table (Place Name Equivalents) gives synonymy for names that are found in more than one form in the literature and on the maps in this report. The second table (Interlingual Glossary) gives the equivalents of various common geographic features in the principal languages used in Central Asia.

The following errata should be noted with respect to place names shown on certain of the maps in this report:

For Khirghiz Steppes read Kirghiz Steppes
For Yarland Darya read Yarkand Darya (River)
For Helmana (River) read Helmand River
For Ozero Bailkal read Ozero (Lake) Baikal

PLACE NAME EQUIVALENTS IN CENTRAL ASIA

Anglicized or older form(s)	New (BGN) form
Cities:	
Chatchil	Hadhal
Jibhalanta, Ulyassutai	Uliastaj
Karashahr	Yenchi
Khotan	Hotien
Kobdo, Jirgalanta	Chovd
Saynshanda	Sajnsand
Tatsienlu	Kangting
Tsetserlig	Cecerleg
Urga, Ulan Bator	Ulaanbaatar
Urumchi	Tihua
Lakes:	
Nam Tsho	Na-mu (Tengri)
Seling (lake)	Zilling
Tangra Tsho	Tangra Yum
Mountains:	
Alai Mountains	Alayskig Khrebet
Alung Kang Range	Alung Gangri
Altai Mountains	Altayn Nuruu
Astin Mountains	Astin Tagh
Bayan Kara Mountains	Pa-Yuan-Kola Shan
Great Snowy Range	Ta Hsueh Shan
K-2	Mt. Godwin-Austen
Khangai Mountains	Hangayn Nuruu
Kokoshili Range	Hoho Shile Uula
Kun Lun Mountains	Kun Lun Shan
Monga Kang Range	Monga Gangri
Mont Dupleix (highest of Monts Dupleix)	Tu-Pei-Li-Ko-Ssu
Muztagh Ata Range	Muz Tagh Ata Tagh
Nyenchen Tanglha	Nyenchhen Thanglha
Shaluli Mountains	Su Lung Shan
Tannu Ola Range	Khrebet Tannu Ola
Stalin Peak	Pik Communisma
Tarbagatay (range)	Sai-Li Shan

The names for the various parts of the Brahmaputra River can be a source of some confusion. From its headwaters in Tibet it flows eastward as the Matsang (Matsang Tsangpo or the Tsangpu) until joined by the Raga Tsangpo at 88°E. There it becomes the Yalu Tsangpo (Tsangpu) or simply the Tsangpo until it exits from Tibet as the Dihang River, to become the Brahmaputra proper where it commences its westward flow down the Assam Valley. Some maps show this entire system as the Brahmaputra River.

INTERLINGUAL GLOSSARY OF COMMON

ENGLISH	AFGHAN	CHINESE	KASHMIRI	MONGOLIAN	NI
desert	dasht gaud	sha-mo		gobi elesen	
hill(s)	ghar	shan	tibba	tologoy	
lake	kol hamun	hai hu t'an ch'ih	tso	nuur nor dalay usa	t
mountain(s)	koh kohi sar ghund	shan kang feng yueh	tagh muztagh sar	hira ula ondor hada	h d
pass	kotal bel	shan-hou	an dawan	hotol dabaan	l
plain	dasht			tala gobi	
range	kuh band saruna	shan-mo ling khan	dhar	nuruu uula haan	l
stream (river)	nala rud hora khwar	ho ch'i ch'uan ch'iang	chu nadi	gol moron su	k g
valley	darra	hsia			

ON P RY OF COMMON PHYSIOGRAPHIC TERMS

NEPA	OLIAN	NEPALESE	RUSSIAN	SANSKRIT	TIBETAN	TURKIC
	i sen		peski		chang	kum
	ogoy		bugor	dongar		tagh
tal	r ay	tal	ozero sar(salt)	kere jhil bil sagar	tsho	kol kul'
hima dand	a or a	himal danda	gora gory golets	parbat giri lhari bum	gongri kangri	tagh
la	ol aan	la	pereval daban	dawan dakhru	la	dawan bel
	a i		ravnina step'		thang	dala
lekh	uu a n	lekh	khrebet yayla kryazh	dhar tlang	ri	tau ala-tau
khol gad	 on	khola gad	dara darya istok reka	ghat khal jhor suti	chhu	su darya
			dol dolina			uzun pamir

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